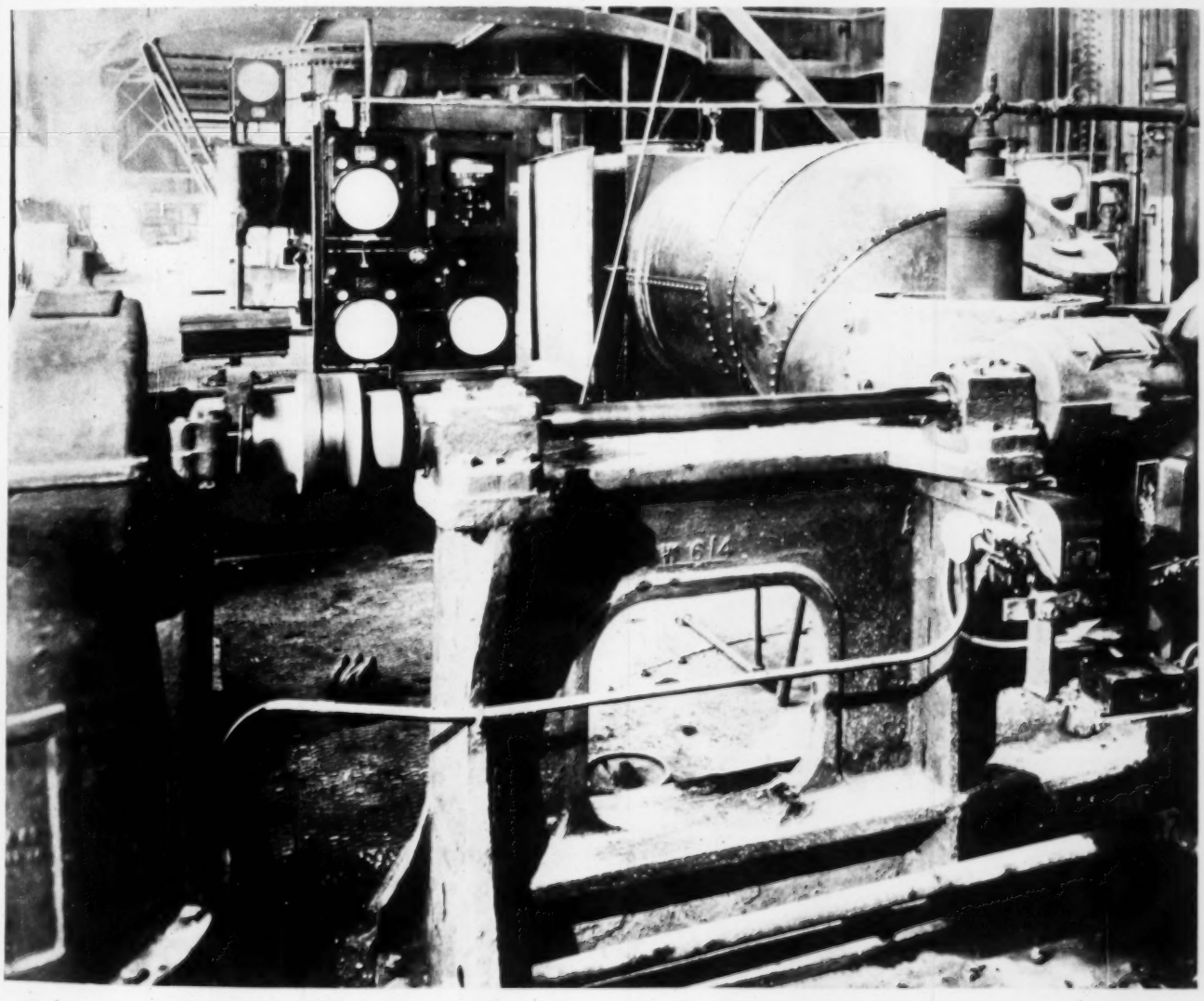
MAY 2 1935

# INSTRUMENTS

THE MAGAZINE OF

# MEASUREMENT AND CONTROL

Volume 8 MAY 1935 Number 5



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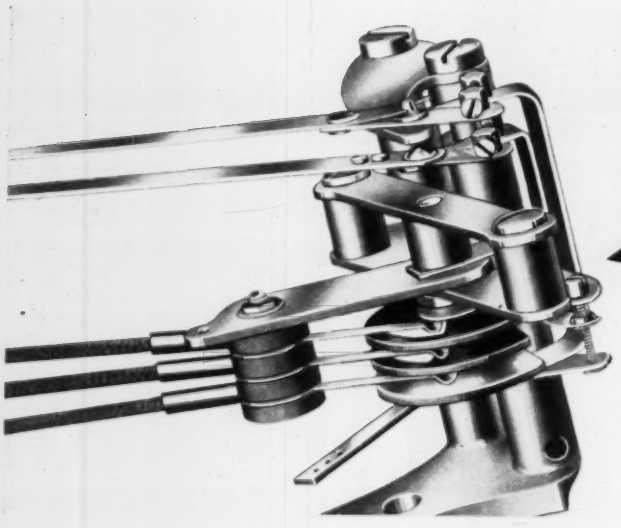

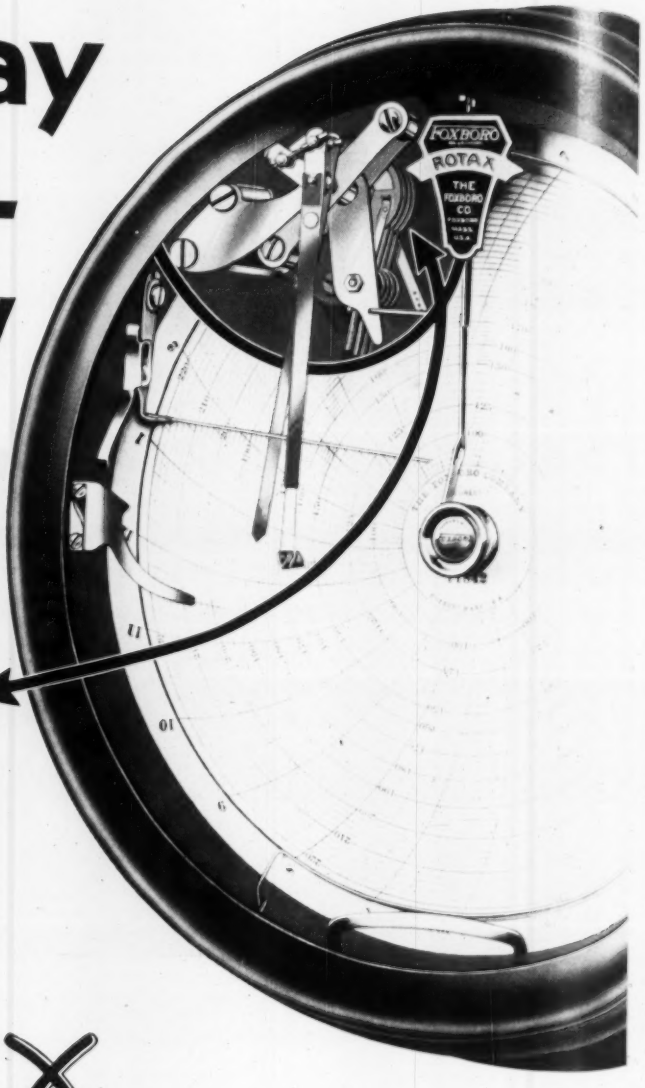


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May, 1935

Dear Subscriber:

The June issue of INSTRUMENTS will include as a special supplement, THE 1935 INSTRUMENTS INDEX (a complete directory of instruments, etc., of trade names and of manufacturers). This important feature is mentioned by Major Behar in his Editorial on page 111. You certainly will want to receive a copy, so make sure that you are a subscriber in good standing. (Look on the envelope in which you receive this copy: if the stenciled date is before May, 1935 your subscription has expired and you should therefore send us your check for $2.00.)

Many of your friends and acquaintances need this Index, and as it will be distributed only to subscribers, I would suggest that you mention this new service to them in time for their subscriptions* to reach us before June 5th. The Index supplement will not be issued separately.

Although this June issue with its reference supplement will be worth many times the subscription price, I am going to make my subscription offer even more attractive. We are publishing a book by C. H. Gibbons entitled "MATERIALS TESTING MACHINES, An Account of their Development, with Special Reference to the Tension-compression-transverse Group." This is a handsome 96-page cloth-bound volume. We will send it to every subscriber (new or renewal) who sends us his subscription with payment attached. If you are an old friend of INSTRUMENTS we will extend your subscription for one year from its present expiration date.

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Richard Rimbach

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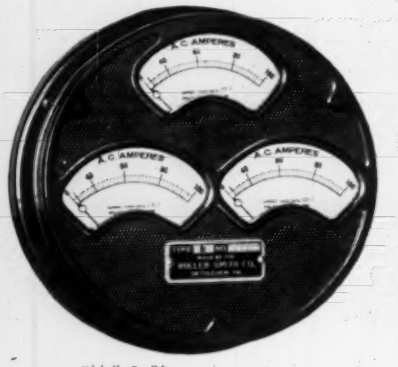

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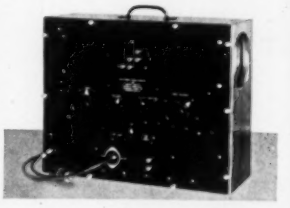

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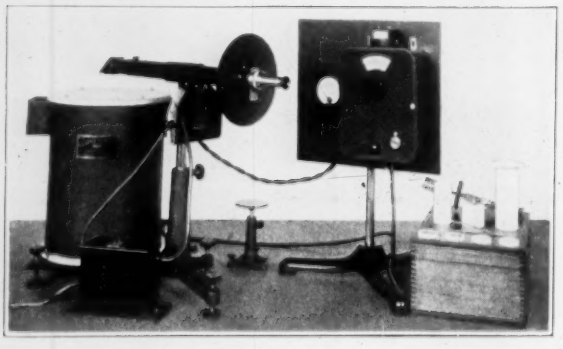

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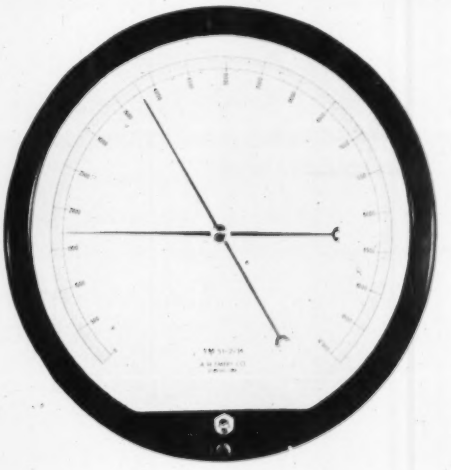

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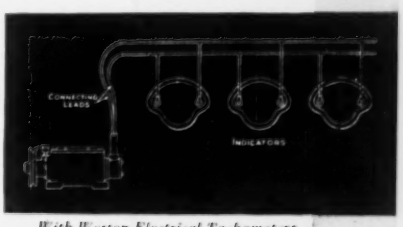


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# INSTRUMENTS

## THE MAGAZINE of MEASUREMENT and CONTROL

## CONTENTS · MAY 1935

Front Cover: Gas Producer Instrumentation
Courtesy The Bristol Co.

The Factor of Merit for Horizontal-shaft Electrical Indicating Instruments . . . . . 112
By F. S. Stickney

Cathode-ray Apparatus Terms . . . . . 115
By Ralph R. Batcher

A Proposed Vacuum-tube Type of "True Direction" Aircraft Instrument . . . . . 116
By J. A. Brooks

A Plan for Centralizing Information on Special Research Instruments and Apparatus . . . 119
By Richard Rimbach

"True Direction" Aircraft Instruments . . . . 119
Discussion by Dr. Ross Gunn

Metering for Special Rate Structures—Part One 120
By Perry A. Borden and M. F. Behar

### INSPECTION AND TESTING

Title Page: Creep Test Control Equipment at Battelle Memorial Institute
Courtesy The Foxboro Co.

The Measurement of Creep of Metals . . . . 128
By Evan A. Davis

Materials Testing Machines—Part Seven . . . 130
By C. H. Gibbons

### NEW INSTRUMENTS

Low-pressure or Draft Indicating Controllers ..... 133
Supervisory System ..... 133
Boiler Water Level Control and Cut-off ..... 133
230-Volt "Variacs" ..... 134
Re-designed Flowmeters ..... 134
Vapor-pressure Recorder ..... 134
Mica Condensers for the Laboratory ..... 134
Fuel-and-air Flowmeter for Furnaces and Kilns ..... 135
Portable Cathode-ray Oscillograph ..... 135
Auxiliary Relays ..... 135
Test Car Column for Gas and Gasoline Analysis ..... 136
Two New Rotameters ..... 136
Pressure, Draft and Differential Recorders ..... 136
A.S.T.M. Daylight Lamp ..... 136
Automatic Pressure-time Cycle Controller ..... 137
Dual Control System ..... 137
Photocell Colorimeter ..... 137
Sequence-repeat Controller ..... 138
Electrometer-tube Type pH Meter and Electrodes ..... 138
New Method and Equipment for Dynamic Balancing ..... 138

Editorial Comment ..... 111
Readers' Comments ..... 114, 119
*Instruments'* Book Shelf ..... 135
Manufacturers' New Literature 136
Buyers' Guide ..... A8
Advertisers' Index..Inside back cover

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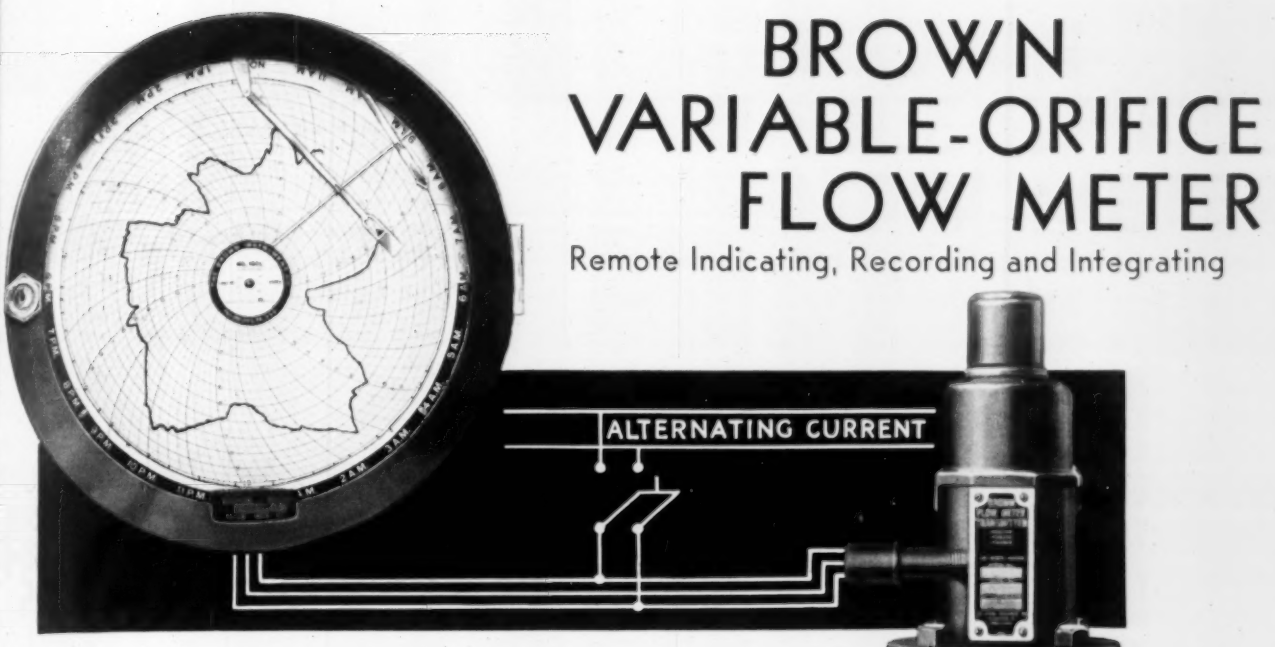


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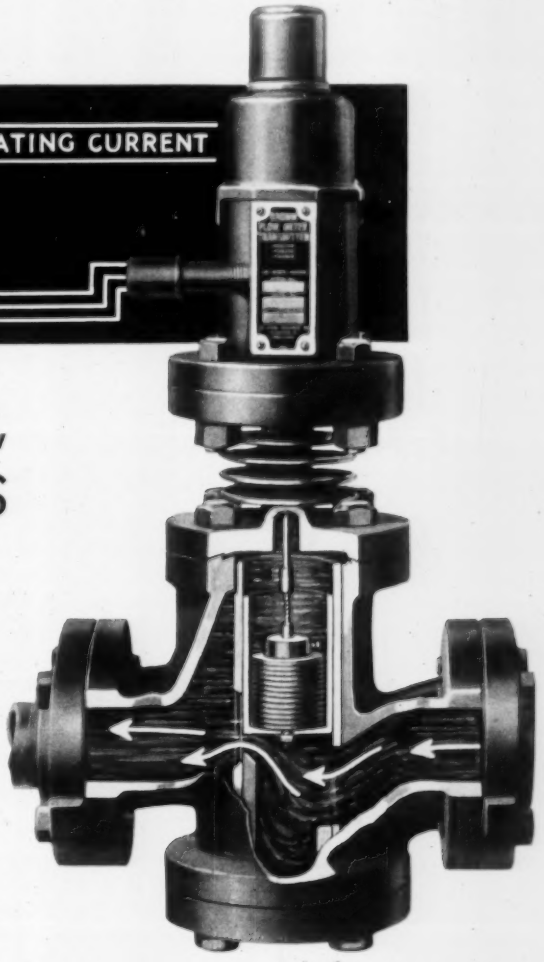
*Write for Bulletin No 21*



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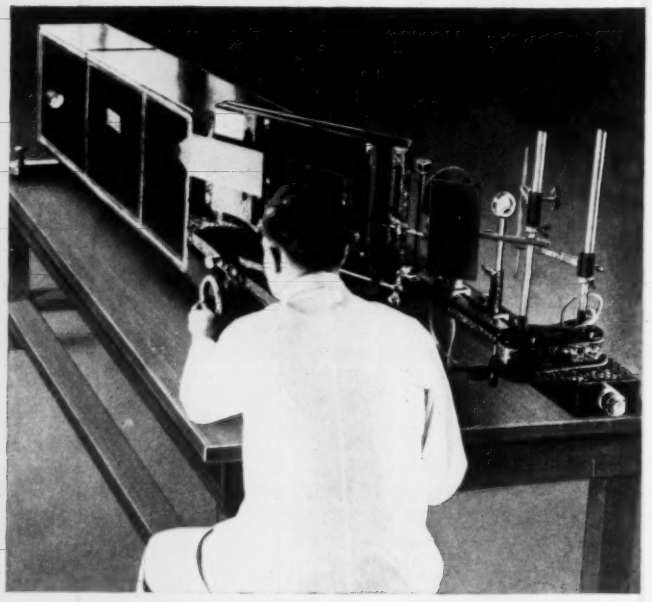

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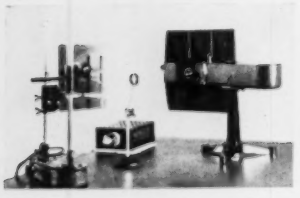

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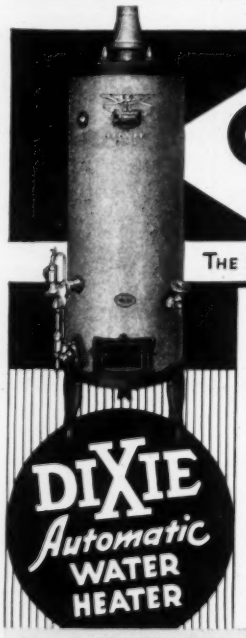

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# EDITORIAL COMMENT

## In This Issue

Never yet have we touted one article as "of fundamental importance to the art" but it is difficult to refrain from doing so with regard to Stickney's contribution. No one has previously analyzed horizontal-shaft electrical instruments with anything approaching his thoroughness. We take particular pride in this study because it was made and written to order. Would that all other projects that we have initiated turn out as successful!

Our esteemed colleague Ralph Batcher poses a number of questions. If *Instruments'* readers cannot provide a full set of answers, who can?

J. A. Brooks describes another of his ingenious attempts to solve the "true direction" instrument problem. We say "another of *his*," for it seems that his was the germ of the idea described in February.

The founder of the Instruments Publishing Co. then proposes a plan for centralizing data on special scientific instruments. It's a good idea, because these special instruments are scattered far and wide and their detailed descriptions are seldom available.

Dr. Ross Gunn, an eminent physicist, lays down some principles which engineers less versed in pure science will do well to observe when they attempt to solve the "true direction" instrument problem.

The first of three instalments on special metering devices for special rate structures takes the next seven pages. Needless to say that Perry Borden's years with "Ontario Hydro" have laid its firm foundation.

At last a brief but comprehensive article on creep tests. Evan Davis merits the thanks of all metal-using industries.

The fascinating history of testing machines by C. H. Gibbons approaches its conclusion. (See page A1.)

The "New Instruments" Section often reflects spurts of progress in various industries. This month we note that four of the twenty items have been developed for the oil and natural gas industry. Boy, phone my broker to buy me 1000 XYZ Pfd!

*The Front Cover Photograph* shows instruments installed on a producer gas machine for the H. E. Millard Co. at the Bradley Quarries, Annville, Pa.

*The Inspection and Testing Title Page Photograph* shows the equipment used for recording and controlling temperatures in creep tests at Battelle Memorial Institute, Columbus, Ohio.

# About You and Us

EDDINGTON and other modern scientific writers, in postulating that the physical universe is made up of relations and relata, point out that the relations are even more important than the relata. In this column we shall strive this month to dwell neither on you nor on us but on you-and-us.

The occasion for such an intimate talk arises from a rather important piece of work now being accomplished by our staff (enlarged for the purpose). It is the compilation of the first complete directory of "who makes what" in the field of Instrumentation. Proud as we are of this undertaking, we cheerfully admit that you subscribers have made it possible and are daily helping to perfect it.

With tens of thousands of index cards being made up and going through various processes, with hundreds of classifications and hundreds of manufacturers, mistakes would seem to be inevitable. The whole job would indeed be slipshod if it were attempted by an inexperienced organization. It is being done nearly perfectly—by reason of the experience which the entire staff of the Instruments Publishing Company has acquired in its seven years of service to you—and is daily acquiring.

So it is largely thanks to you that *The 1935 Instruments Index* is taking shape as a reference compilation which will prove as useful and influential as the old-established annuals of the building, mining, chemical and other fields. As announced on the inside-back-cover last month and on the first advertising page of this issue, this Index will be a supplement to the June issue. It will be bound with the June issue and sent only to subscribers. (Tell your friends.)

Some twenty-five years ago an essay entitled "The Creative Audience," by a brilliant music critic, influenced us profoundly. Often during our editorship of *Instruments* we have recalled his penetrating observations on symphony-hall audiences and have mentally applied them to all of our 3000-odd regular subscribers (as well as to some of our uncounted thousands of other readers). The most curious part of it all is that this great and constructive force emanating from you to us is like an ocean made up of raindrops: few remarks are uttered or written with the intent of educating *Instruments*, but the sum of all these individual contacts is what makes *Instruments!*

M. F. BEHAR

# The Factor of Merit for Horizontal-shaft Electrical Indicating Instruments

By F. S. STICKNEY*

THERE are at least ten times as many horizontal-shaft electrical instruments in use in industry as there are of the vertical-shaft type treated by R. W. Carson in his recent *Instruments* article.[1] Therefore a discussion of the merit factor for the majority of electrical instruments requires an analysis of performance factors for the horizontal-shaft type. Carson has stated that the minimum torque of a vertical shaft electrical instrument of the conventional two-pivot type can be expressed:

$$T = KW^{1.3} \qquad (1)$$

where $T$ is the torque in millimeter-grams for full scale deflection, $W$ is the weight of moving parts in grams, and $K$ is a function of the length of the scale. The factor $K$ was introduced under the well-founded assumption that errors due to pivot friction become more conspicuous on long-scale instruments, and that for such instruments a reduction in the angular friction error is necessary to reduce the observed friction at the tip of the pointer to a negligible value. This means that for a given movement weight, a higher torque is required for a longer pointer and scale if the accuracy ordinarily expected from the longer scale is to be achieved.

Horizontal-shaft instruments differ from vertical-shaft instruments in many respects. Neglecting a few types of "edgewise" instruments on the market, the majority of permanently mounted electrical instruments are operated with the pivot axis horizontal. Fig. 1 shows the fundamental structure of bearings for a typical horizontal-shaft instrument. Analysis of the static forces acting on the horizontal movement shows them to be more complex than for the vertical-shaft instrument. In Fig. 1 the movement is supported by the jewel cups as represented by forces $J_1$ and $J_2$, perpendicular to the contact surfaces. The surfaces of contact between pivots and jewels do not fall on the major axis of the pivots. Due to the necessary amount of end play, the probable departure of the center of gravity of the movement from a point midway between the pivots and the effect of springs and unsymmetrical electrical torques, the contact area between pivot and jewel may occur in a number of places. Fig. 2 shows a possible case where unsymmetrical forces have caused one pivot to rise and the other to fall. These diagrams demonstrate that an increased number of variables must be taken into account when passing from a study of vertical shafts to horizontal shafts, and that the geometrical design of both pivots and jewels becomes of greater importance. Another variable to be considered in selecting a factor of merit is that some horizontal-shaft instruments are used as standards for accurate work while others, although having long pointers and large scales, may be made so for purposes of long distance visibility, so that permissible error may not necessarily be a function of scale length in all cases.

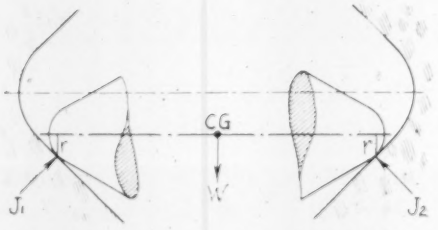


**Fig. 1. Bearings of an electrical indicating instrument with a horizontal shaft. Symmetrical pivot and jewel contours and symmetrical loading are assumed.**

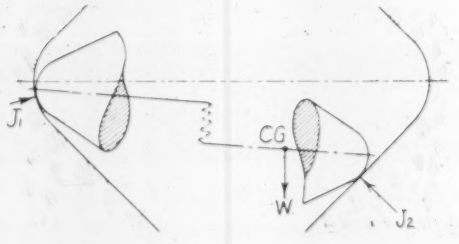


**Fig. 2. Effect of unsymmetrical loading on the working position of the bearings. Unsymmetrical jewel cavity slopes have a similar effect.**

Referring to Fig. 1, Goss[2] has shown that pivot friction for a horizontal shaft is proportional to a radius $r$ measured between the main axis of the pivots and the center of the area of contact between pivot and jewel. According to Goss:

$$T_f = \mu W r \qquad (2)$$

where $T_f$ is the frictional torque, $\mu$ is the coefficient of sliding friction, $W$ is the weight of the movement, and $r$ is the shortest distance between the main axis and the center of the area of contact.

The assumption is made that radius $r$ is practically independent of weight, that $\mu$ is constant, and Goss finally arrives at the conclusion that $T_f = KW$ and that the factor of merit $K$ for a horizontal-shaft instrument should be based on the ratio $T/W$. But this conclusion that $T/W$ can be used alone as a factor of merit for horizontal-shaft electrical instruments fails in practice. It can be experimentally demonstrated that of two instruments of identical design and torque weight ratio, one may have frictional torque of negligible value, while the other may show excessive friction. A visual inspection of these pivots and jewels will disclose no apparent defects, and will show equal and satisfactory polish on all important surfaces. Yet one instrument may show a frictional torque several times that of the other.

This difference in performance of instruments with identical torque weight ratios arises from differences in contours of pivot and jewel. In grinding sapphires, a perfect cavity contour is the exception rather than the rule. The contour of a jewel cavity can be readily determined by forcing a soft wax or lead point into it under pressure, and examining the resulting impression under high magnification. Such studies have been made covering many thousands of jewels, and no two cavities are ever found exactly alike. Both flank angle and cup radius vary considerably as well as pivot radius and pivot angle, depending upon the process used and the closeness of inspection.

Fig. 3 (a) is a theoretical average normal jewel cavity.

*Westinghouse Electric & Mfg. Co., Instrument and Meter Works, Newark, N. J.

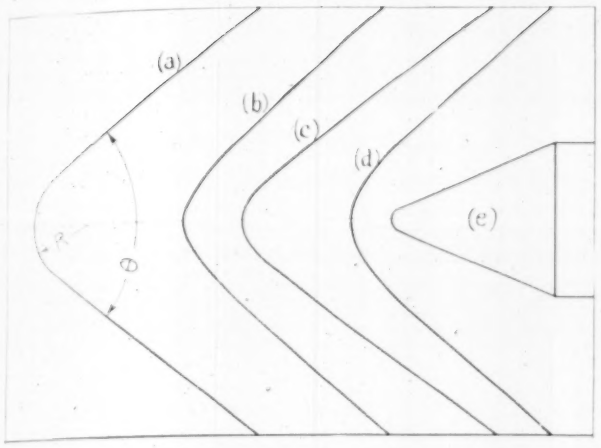


Fig. 3
(a) Hypothetical jewel cavity having true radius and truly conical sides.
(b), (c), (d) Tracings made from actual jewel cavities showing normal acceptable variations in contour.
(e) A theoretical pivot with truly spherical tip.

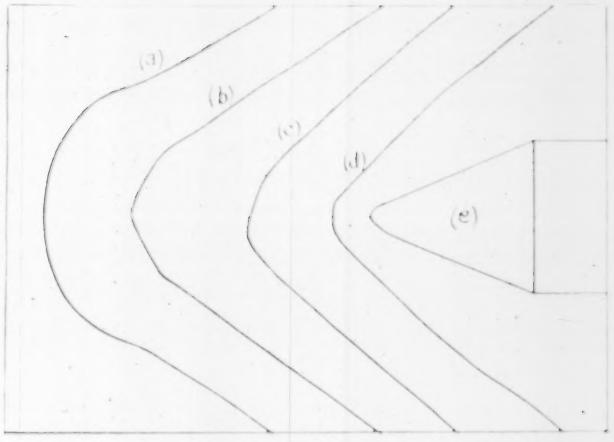


Fig. 4. Tracings from actual jewel cavities, showing undesirable contours which must be eliminated by careful inspection in order to avoid excessive friction in well-designed instruments.
(a) Excessive radius and variable slope.
(b) Flat slopes near bottom of cavity.
(c) Unsymmetrical cavity with flat spot.
(d) Radius too small with bottom of cavity flat.
(e) An overloaded pivot.

as reproduced by the skill of the draftsman. No cavity is ever like this. Figs. 3 (b), (c) and (d) show actual jewel cavities with the necessary manufacturing tolerances on dimensions for radius $R$ and angle $\theta$. These cavities illustrate approximately the variations which must be accepted in order to obtain jewels in commercial quantities. Figs. 4 (a), (b), (c) and (d) are tracings made from actual jewels, showing some of the contours which, if not eliminated, will tend to produce excessive friction in spite of the designer's best calculations in respect to torque and weight.

Now let us see what happens when an instrument is built with perfectly good pivots and jewels as good as money can buy. Remember that Figs. 3 (b), (c) and (d) represent reasonable tolerances in grinding sapphires by the best domestic and foreign artisans.

Referring to Fig. 5, one end of the movement is supported by the jewel reaction $J$ normal to the surface of contact. If $W$ represents the weight supported by the jewel, then $J$ can be resolved into a vertical component $W$ and a horizontal component $P$. Then

$$J = \frac{W}{\cos \frac{\theta}{2}} \qquad (3)$$

and

$$P = W \tan \frac{\theta}{2} \qquad (4)$$

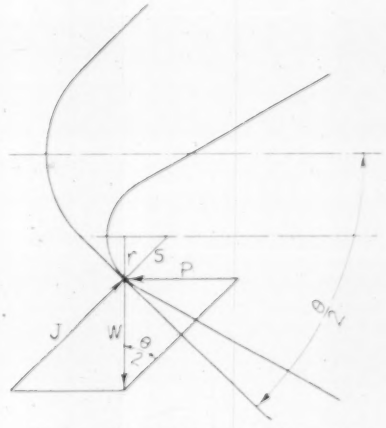


Fig. 5. Frictional torque is proportional to $J$ and $r$. Both $J$ and $r$ are functions of pivot and jewel contours.

In the common condition of unsymmetrical loading shown by Fig. 2, the heavily loaded pivot will fall, and the more lightly loaded pivot will rise, on the slopes of the jewel cavities until the horizontal reactions $P$ at both ends of the movement become equal. To produce equilibrium, the slopes at the points of contact must necessarily be different for the two bearings. The more heavily loaded pivot produces the most friction, other conditions being equal, and this pivot also is subject to the higher working stress.

If $\theta$ is the total angle of the jewel cavity at the surface of contact, obviously the normal force $J$ will increase rapidly as $\theta$ approaches 180°. In practice, the jewel angle is seldom less than 60° and seldom greater than 120° for horizontal shaft instruments, so $J$ may vary from 1.15 $W$ to 2 $W$ if the surface of contact falls upon the conical side of the jewel. But due to unsymmetrical loading, one pivot is usually forced well into the radius portion of the jewel, and $J$ may be considerably higher than 2 $W$ for the more lightly loaded pivot.

Friction is really a function of the normal force $J$ rather than the vertical weight $W$. Taking this into account equation (2) becomes:

$$T_f = \mu J r \qquad (5)$$

and combining equations (3) and (5)

$$T_f = \frac{\mu W r}{\cos \frac{\theta}{2}} \qquad (6)$$

But $r$ is a variable depending upon the size and contour of the pivot and the location of the point of contact. If the pivot has a truly spherical tip with radius $S$, the friction radius will vary according to the relation:

$$r = S \cos \frac{\theta}{2} \qquad (7)$$

Combining (6) and (7), the frictional torque for a pivot with truly spherical tip becomes:

$$T_f = \frac{\mu W S \cos \frac{\theta}{2}}{\cos \frac{\theta}{2}} = \mu W S \qquad (8)$$

Hence, for a spherical pivot tip the friction is directly proportional to the radius of the tip and the weight carried by it. But for a pivot tip of any other shape equations (7) and (8) do not hold, and the frictional radius $r$ becomes a complex variable. A pivot having a flattened tip would show constant radius of contact for any jewel

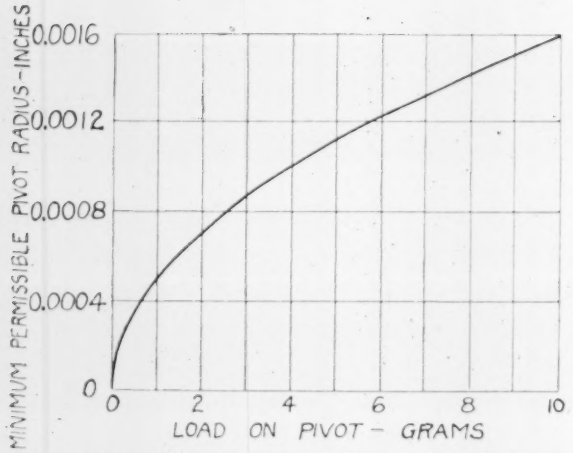


**Fig. 6. Theoretical safe relation between pivot loading and pivot radius as derived by Stott. In practice pivot loading can be higher than indicated by this curve for static loading, on account of the curvature of jewel cavities.**

angle. A perfectly sharp point would have zero radius and zero friction, but would not be able to sustain a load without deformation. In practice, an exact spherical pivot point being unattainable, $r$ must be considered as a function of both jewel and pivot contour.

To avoid deformation of pivots it is necessary to keep working stresses at all times below a critical value. Stott[3] has experimentally determined the critical stress for conical pivots, and has developed a mathematical relation between the load carried by the pivot and the minimum safe radius. This relation is shown graphically in Fig. 6 for a hardened steel pivot with spherical point in contact with a flat surface assumed to have no elastic deformation. In practice, pressures somewhat higher than those obtained from the curve can probably be allowed, as the pivot invariably comes to rest upon a curved portion of the jewel cavity. No data are available on the elastic properties of sapphire, but such elasticity will further increase the allowable working pressure.

End play is another variable which may influence the frictional performance of an instrument. In practice, a reasonable amount of end play is provided as insurance against possible jamming due to different thermal expansions of the movement and supporting frame.

Normal end play, with normal unsymmetrical loading of the movement, can be assumed to produce somewhat different frictional torques in the two bearings of an instrument. The exact amount of axial sliding, the final working position of the bearings, and the resulting frictional torque are incapable of mathematical solution except in the ideal case.

The amount of end play influences the working stress in the pivot at the surface of contact. A small amount of end play brings the contact surface of both bearings well up into the narrow portion of the jewel cavity, where the radius of curvature is small. This tends to increase the area of the surface of contact, and decrease unit stress. On the other hand, a large amount of end play will allow the more heavily loaded pivot to slide down the slope of the jewel to a point where the radius of curvature is larger, thus decreasing the area of the surface of contact, and increasing the working stress.

End play introduces a still greater variable in instruments used for service where vibration is encountered. Here, unit stress in the pivots of a given instrument can be increased to a high value by allowing excessive end play. If there were no end play at all, the pivots would have to carry only static load plus forces of acceleration. But with end play the movement will fail to follow the forced motion of the jewels, and will absorb energy at a high rate during brief moments of contact. The movement may, at certain frequencies, develop a resonant vibration of its own, with resulting hammering of pivots against jewels. These conditions develop extremely high unit stresses in bearings, and require a liberal factor of safety as compared to static loading.

Stott[3] has shown that the coefficient of friction of sapphires may vary considerably depending upon the orientation of the crystal structure with respect to the size of the cavity. Measured frictional variations of the order of 2.2 to 1 were reported, due to this cause.

The type of service for which an electrical instrument is intended introduces still another variable. For stationary service, a relatively sharp pivot can be used to reduce friction to a small value. For transportation service or for any service where the instrument is subject to continued vibration, the aspect of the friction problem changes. As long as the vibration continues, static friction does not appear. But when the vibration ceases, the laws of static friction begin to operate, and if accuracy is expected under both vibration and static conditions it becomes necessary to design the instrument with higher spring torque or less weight. Either of these expedients will probably increase the electrical energy required to operate the instrument.

The conclusion is far from mathematical. No formula alone can show the difference between an accurate instrument and an inaccurate one. The only certain method is that of actual test. Even with a favorable torque/weight ratio, the success of a given type or make of instrument depends much more upon the care with which its jewels, pivots, springs, and balancing adjustments are manufactured and inspected, than upon arbitrary torque/weight ratios. A high ratio of torque to weight will sometimes conceal inferior bearings and other defects. But high torque requires high energy consumption. The real test of an instrument is its ability to operate in a satisfactory manner with a limited amount of energy.

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# "Valuable Literature"

*To the Editor:*

. . . I am sorry I did not get subscriptions from all the men at our plant who are engaged in servicing instruments and controllers, but have not given up. If I am able to procure any more subscriptions I will gladly send them in.

I regret very much that I did not know of your publication while I was actually engaged in the installation and servicing of refinery instruments, for I feel it would have been of considerable help, hence did not hesitate to recommend it to my friends, even though it were, you might say sight unseen.

In an issue of *The Refiner* last year I read of your books, "Fundamentals of Instrumentation" and "Temperature and Humidity" and was permitted to order them for our plant library. We now have also "The Engine Indicator" in our library. It was the desire to find out more about such valuable literature that prompted me to write you.

It is my firm belief that you could increase your circulation by calling your publications to the attention of plant managers, electricians, instrument maintainers, etc., not only in refineries but in all industries as they are all becoming more instrument conscious.

E. J. Dearborn

*Newark, Ohio,*
*February 9, 1935.*

# Cathode-ray Apparatus Terms

By RALPH R. BATCHER*

IN regard to certain terminology regarding cathode ray apparatus, which the writer discussed recently with the editor of *Instruments*, the writer now presents his own ideas in the matter, for comments by *Instruments* subscribers. The I.R.E. has not yet standardized these terms, so that in editing manuscripts for the *I.R.E. Proceedings*, the writer has had to use his own judgment —which in most cases was to let each particular author's own terms ride. In the following list of some of the items that have been considered, the first term in any particular paragraph is the term that the writer has used in his own writings.

OSCILLOGRAPH, OSCILLOSCOPE. This is a controversial subject. While accuracy in terminology seems to favor the latter term, an investigation of present usage (I have recently examined about 1200 technical articles on this subject, published during the last thirty-five years) shows that more than 90% of the authors use "oscillograph." The suffix "graph" by no means definitely connotes writing, printing or other recording equipment (telegraph, phonograph, etc.). It seems that since a graphical or two-dimentional figure represents a typical oscillogram obtained with a cathode ray tube, the term OSCILLOGRAPH is justified. It also seems that many engineers tie up the word OSCILLOSCOPE with particular apparatus built by one or two companies, by reason of the stress they have placed on this word in their advertising.

CATHODE RAY, ELECTRON JET, ELECTRON BEAM, ELECTRON STREAM, etc. Usage favors the first, although modern electron principles might give weight to the second term.

CATHODE, ANODE, etc. The meaning of these terms is established by ordinary electron tube practice. In the cathode ray tube, however, several "anodes" may be used. I have found it desirable to restrict the term "anode" to that electrode that determines the final velocity of the electrons. Other intermediate "anodes" are, therefore, called "focusing electrodes" with the prefix "first," "second," etc., as required. The electron lens principles might require that a negative potential (with respect to the cathode) be applied to certain of these electrodes, which emphasizes the desirability of not using the term "anodes." The function of these electrodes is not to collect electrons (the usual meaning of anodes) but to produce and to control certain concentric electrostatic fields. My own terminology, which permits only one cathode and one anode for each jet within the tube, will not take care of certain types of tubes (comparatively rare) which have a two-stage acceleration: that is, in which the ray is speeded up rapidly in the region next to the screen. This is at variance with the data sheets of some manufacturers who designate all odd electrodes within the tube "anodes."

FOCUSING FACTOR. A term used to denote the effectiveness of the focus. It may be defined as the ratio of the diameter of the spot to the diameter of the screen. This term has not received much attention and the writer does not know if it is original or not. Test conditions, however, must be stated, such as "tests made with the deflection plates shorted, and with maximum rated anode potential and bias set half way between zero and cut-off." Inasmuch as in some makes of tubes focusing is not equally effective at all points the writer recommends that an average spot diameter be taken, measured at four points taken at the intersection of a circle (having a diameter equal to 70% of the nominal diameter of the screen) and the normal axes.

NORMAL AXES. The traces of the spot produced when an alternating potential is applied successively to each pair of deflection plates. These axes usually intersect near the center of the screen.

WEHNELT CYLINDER, FOCUSING CYLINDER, FARADAY SHIELD, etc. The first term is generally used, although it is doubtful if the shields used by Wehnelt in his tests correspond exactly to the cathode cylinder as used in present-day tubes. The term CONCENTRATION CYLINDER is probably the most accurate as its function is to concentrate the diverging bundle of rays around the cathode and its effect on the focusing of the spot at the screen is secondary.

ELECTRON FOCUSING, ELECTRONIC LENS FOCUSING, and several other terms have been used to refer to focusing by concentric radial fields. This principle is ordinarily, although not necessarily, used in high vacuum tubes. It is used to distinguish it from GAS FOCUSING which requires a certain amount of gas ionization for counteracting dispersion. It is a characteristic of gas focusing that a careful control is necessary of the filament temperature, whereas with ELECTRON FOCUSING this adjustment is not necessary. It is quite possible, however, that this characteristic is not definite enough in the case of gas-focusing as it is quite possible that the electron emission can be controlled accurately enough by the use of inverse cathodes, and other devices, which would do away with the necessity of a filament rheostat. ELECTROMAGNETIC FOCUSING by the use of concentric coils is applicable to both gaseous and high-vacuum tubes, and the position and current through these coils can both be varied at will. This is probably true also in the case of ELECTROSTATIC FOCUSING with internal electrodes. The effect of the gas, however, is rather difficult to predetermine, and the position of the plates, therefore, hard to locate. Since it is impossible to change these electrodes around in a tube once it is assembled, it is usual practice to pump such tubes as hard as possible.

It would be desirable to have some definition of the vacuum conditions in a tube that would cover all cases.

SCREEN BRILLIANCE. This factor is usually expressed as a series of curves. At present such curves do not ordinarily state the color limits over which the data were taken, in the determination of the candle power per unit area. Brilliance factor is usually important only when photographic records are to be made, and the candle-power over the visible spectrum is not sufficient.

SCREEN SPEED. The fluorescent decay period of a screen is now rated as normal and fast. It is desirable that at least three ranges be defined:

*Fast*—the decay curve of the order of 100 micro seconds or less.

*Normal*—the decay curve of the order of 0.02 second.

*Slow*—the decay curve with a period of >0.5 second.

At a later date additional information on this subject will become necessary. A particular tube, for instance,

(Continued on page 118

*Radio and Cathode-ray Engineering Consultant, Hollis, N. Y.

# A Proposed Vacuum-tube Type of "True Direction" Aircraft Instrument

By J. A. BROOKS*

### INTRODUCTION—DISCUSSION OF THE DUDLEY-SLEPIAN ARTICLE

IN the February issue of *Instruments* A. M. Dudley reports an ingenious device for indicating the true direction of movement of aircraft, and reports also Dr. Slepian's opinion thereon. Dr. Slepian raises a question which goes to the roots of our concepts of electricity and requires a careful interpretation of the Theory of Relativity. Fig. 4 in Mr. Dudley's article shows the generator cooperating with the vertical component of the earth's magnetic field to be a loop formed by a conductor and leads connecting the conductor to the slip rings. For the purpose of clarifying the discussion it might be well to consider the generator as comprising only the conductor, cut at the center, and with the inner end of each half connected to a slip ring.

It is well known that when a conductor is moved laterally through a magnetic field a difference of potential is set up between its two ends. It is generally believed that this difference of potential is caused by a redistribution of the free electrons in the conductor, which results in fewer electrons at the positive end and a greater number of electrons at the negative end. If the conductor is moved through the magnetic field and at the same time rotated about an axis perpendicular to the plane containing the direction of movement (which in turn is assumed to be perpendicular to the lines of force acting upon the conductor) then each end of the conductor is alternately positive and negative and of opposite sign from the other. This should result in the flow of an alternating current in the conductor, by reason of reversals in the polarity of the potential generated between its ends. If slip rings are inserted in the conductor at the axis of rotation and an impedance connected across the slip rings, the alternating current flowing through the impedance should set up an alternating potential.

Now assume the same conductor to be rotated, but without rectilinear movement, in an electrostatic field, the lines of force of which are parallel to the plane in which the conductor is rotated. A similar alternating current should be set up in the conductor as a continuous redistribution of electrons takes place in the conductor to maintain zero potential between its ends.

Dr. Slepian points out that if the conductor described is rotating about an axis in a magnetic field parallel to the axis and in an electrostatic field perpendicular to the axis, and at the same time moving rectilinearly through both fields in a direction perpendicular to the axis, the flow of electrons in the conductor will be influenced by the action of the electrostatic field as well as by action of the magnetic field. He further points out that the effect of the magnetic field cannot be separated from the effect of the electrostatic field unless the direction and magnitude of the electrostatic field are known. He says also that the conductor cannot be shielded from the electrostatic field without nullifying the effect of the magnetic field, because the shield in moving with the conductor has a potential generated in it by cutting the same magnetic lines of force, and that this potential sets up an electrostatic field inside the shield which exerts forces equal and opposite to the forces exerted by the action of the magnetic field.

### A SOLUTION MAY LIE IN THE THERMIONIC PRINCIPLE

The writer concurs with Dr. Slepian's views insofar as the form of the device described by Mr. Dudley is concerned. On the other hand the writer does not believe that Relativity renders impossible a solution of the problem, and therefore suggests a circuit in which a given magnetic or electrostatic field produces different effects depending upon which part of the circuit is subjected to its action. The plate circuit of a vacuum tube falls in this category, as is apparent by the difference in effect produced by a potential set up near its cathode as compared with the same potential set up near its plate, the potential differing slightly from the cathode potential in the first case and from the plate potential in the second case.

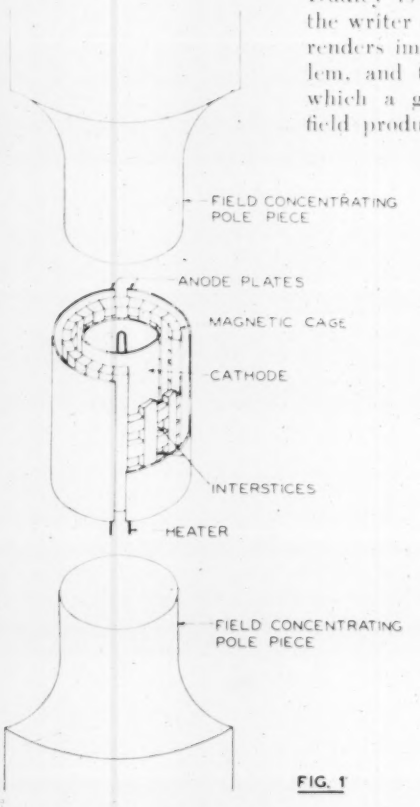



FIG. 1

It therefore is proposed that the vacuum tube generator described below be substituted for the vertical component generator in the device described by Mr. Dudley. In the vacuum tube generator the vertical component of the earth's field is made to act upon the plate current of a vacuum tube at a point near the cathode where the action is most effective. The plate of the vacuum tube serves as an electrostatic shield. The forces on the electrons due to the action of the magnetic field are equivalent to what the forces would be if the tube were of the conventional three-element design, with a potential set up from the grid to the cathode equivalent in value to the potential which the magnetic field would generate in a single conductor. This potential is set up also between the plate and the cathode, but here its effect is negligible as compared to its effect when applied in the vicinity of the cathode.

*Assistant Electrical Engineer, New York and Queens Electric Light & Power Co.

### DESCRIPTION OF PROPOSED DEVICE

The proposed vacuum tube generator, Fig. 1, consists of a multi-element thermionic tube having: (*a*) a heater, cathode and two plates, all as usual, and (*b*) an added element which supplants the control grid used in existing 3-element vacuum tubes. This element acts to produce an effect which is somewhat similar to the effect produced by the control grid in the conventional 3-element thermionic devices; but, instead of the effect being caused by the setting up of an electrostatic field between the control grid and the filament, it is produced by causing a magnetic field having lines of force substantially parallel to the long axis of the cathode to pass through the path of the particles of electricity moving from the cathode to the plates in such a way that these particles cut the lines of force. Due to this cutting of the magnetic field, a force is exerted on the particles of electricity in the direction of the plate or in the direction of the cathode depending upon the direction of movement of the magnetic field with respect to the path of the electrons emitted from the cathode. When the force is toward a plate the electrons are accelerated and the plate current is increased. When the force is toward the cathode the electrons are decelerated and the plate current is decreased. The new element surrounds the cathode and consists of bars of magnetic material, separated from one another by intervals approximately equal to their width, and arranged in a cylindrical configuration ("squirrel cage") with the cathode approximately coincident with the long axis of the cylinder. The intervals between these bars may be filled partially by bridge pieces, leaving however a sufficient number of interstices through the element for the electrons to travel between the cathode and the plate. Fig. 2 is a plan view of Fig. 1. The use of two plates—located on opposite sides of the cathode—makes the tube a duplex thermionic device so that it can be considered as two thermionic tubes. An inspection of the connection diagram in Fig. 3 shows that the tube is actually used as such.

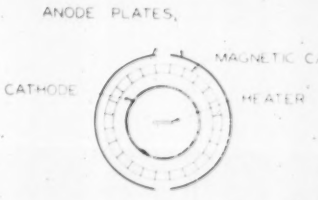


FIG. 2

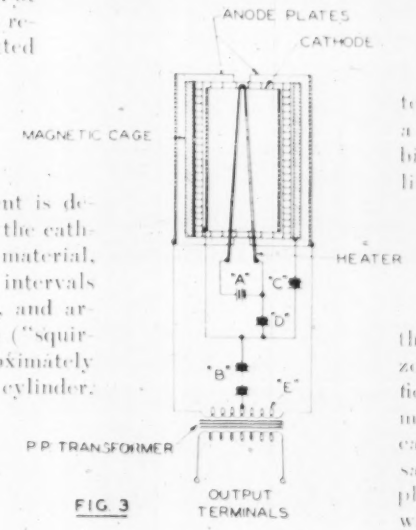


FIG. 3

The upper and lower pole pieces shown in Figs. 1 and 4 are of high-permeability magnetic material and serve to concentrate the lines of force set up by the vertical component *V* of the earth's magnetic field. The pole pieces are designed to saturate at a magnetomotive force well below the usual strength of *V*, so that the number of lines of force through the magnetic cage of the tube are maintained substantially constant even though the field strength of *V* may vary somewhat.

Referring to Fig. 3, the heater is energized from a source of current which is connected to the cathode through battery *D*. The magnetic grid is connected to the cathode through battery *C*. The two plates are connected to the cathode through output device *E* and battery *B*. The output device may be any of the well known arrangements of output coupling but in the case illustrated it consists of an output transformer, the primary of which is center tapped. The center tap is connected to the *B* battery and the ends are connected to the two plates. This is known as a push-pull connection and operates as such. All of these connections and uses of batteries are well known and need no further explanation.

### PRINCIPLES OF OPERATION

The operating features of the vacuum tube generator can be described progressively as follows: The tube is mounted with the long axis of the cathode parallel to *V*. When the tube is at rest with respect to the earth's surface, and all circuits shown in the wiring diagram in Fig. 3 are closed, the cathode is heated and emits electrons which are attracted to the two plates, setting up plate currents in the two plate circuits. Adjustment of the *C* battery voltage should affect the plate current in a manner similar to adjustment of the grid bias in the conventional 3-element tube. The lines of force in the magnetic cage, set up by *V*, do not affect now the passage of electrons between the cathode and plate, because these lines are confined within the bars of the magnetic cage and therefore are not present in the interstices through which the electrons pass. The horizontal component *H* of the earth's magnetic field is confined in the small bridge pieces of magnetic material between the bars of the cage and it therefore does not effect the passage of electrons between the cathode and plates for a similar reason. In terrestrial zones where *H* is small compared to *V*, these bridge pieces need not even be of magnetic material, after the lines of force set up by the vertical component have been concentrated by the use of magnetic material as described above.

The tube is now rotated about the long axis of the cathode, causing the lines of force set up by *V* to thread through the magnetic grid from one bar of magnetic material to the adjacent trailing bar of magnetic material, in such a manner that they are still confined within the cage wall and are not present in the hollow inside of the cage. As these lines pass longitudinally through the interstices, they are cut by the electrons traveling radially through the interstices. The lines exert on the electrons a force which is in the direction of the plate or in the direction of the cathode depending upon the direction of rotation of the tube. However, the direction of this force, if toward the cathode when exerted on an

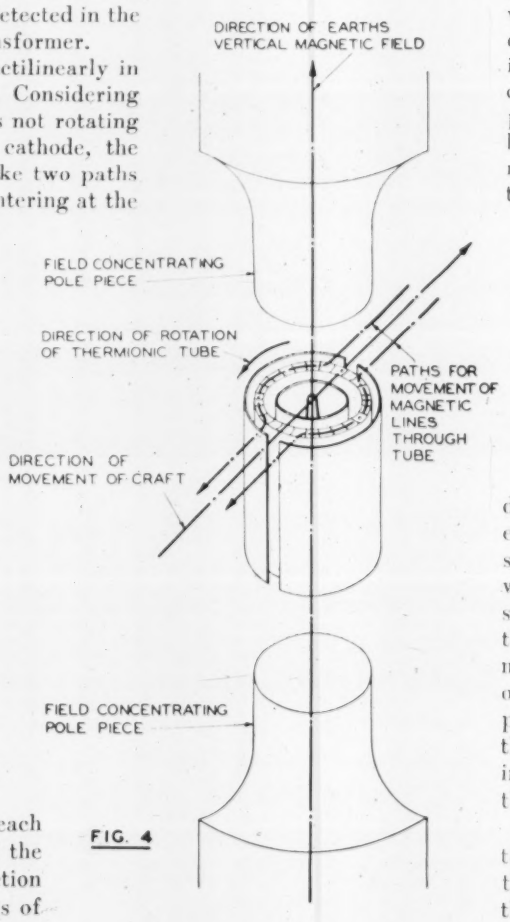
## *Instruments'* Open Forum on the "True Direction" Problem

**In our February issue we printed an article reporting one type of proposed instrument and stating that Relativity would prevent it from working. Our editorial comment concluded as follows: ". . . need of open discussion. We particularly desire reports of investigations actually conducted, with analyses of results obtained . . . Send them in!" It is our hope that this open forum will hasten the solution of aviation's most perplexing instrument problem.**

—M. F. BEHAR

electron passing to one plate, is also toward the cathode when exerted on an electron passing toward the other plate; and if toward the plate in one case it is also toward the plate in the other case. Therefore the change in current in one plate circuit has a corresponding change of current in the other plate circuit and—since the change is similar in both plate circuits—no change is detected in the secondary of the output transformer.

The tube now is moved rectilinearly in a plane perpendicular to *V*. Considering for a moment that the tube is not rotating about the long axis of the cathode, the lines of force set up by *V* take two paths through the magnetic cage: entering at the leading side of the cage, where they divide, substantially half of them passing to the trailing side through one semi-circular section of the cage and the other half passing to the trailing side through the opposite semi-circular section of the cage. (By semi-circular sections of the cage are meant the sections formed by the plane which contains the direction of movement and the long axis of the cathode.) These paths are illustrated in Fig. 4. It is now apparent that the electrons in the interstices cut the lines of force set up by *V*. Assuming for the moment that the two plates are as shown in Fig. 4, that is, each plate entirely on one side of the plane which contains the direction of movement and the long axis of the cathode, the force exerted on the electrons in the interstices on one side of the plane is in the same general direction as the force exerted on the electrons in the interstices on the other side of the plane, but the arrangement of the elements of the tube is such that this force is toward one of the plates and away from the other plate. Therefore the plate current in one of the plate circuits is increased and the plate current in the other plate circuit is decreased, the dissimilar change in plate current in the two plate circuits setting up a voltage across the secondary of the output device. If it is now assumed that the tube is both rotating about the long axis of the cathode and at the same time moving perpendicularly to *V*, then we have a combination of the two actions described separately above. The combination can be thought of in terms of increasing the rate of cutting of lines of force set up by *V* on one side of the plane and decreasing the rate of cutting on the other side of the plane. If the rectalinear movement is not along a magnetic meridian, then the electrons passing from the cathode to the plates will be caused to cut lines of force set up by *H*. The force resulting will be in a line parallel to the long axis of the cathode and the sense of the force will depend upon whether the tube is moving east or west. However, the sense of forces set up on the electrons will be the same whether the electrons are passing on one side of the plane referred to above or on the other side of that plane. These forces may tend to deflect the electrons upward or downward and may therefore affect the plate current in the two plate circuits but the effects should be mutually compensating and should therefore not appear across the terminals of the output device.


DIRECTION OF EARTHS VERTICAL MAGNETIC FIELD
FIELD CONCENTRATING POLE PIECE
DIRECTION OF ROTATION OF THERMIONIC TUBE
PATHS FOR MOVEMENT OF MAGNETIC LINES THROUGH TUBE
DIRECTION OF MOVEMENT OF CRAFT
FIELD CONCENTRATING POLE PIECE
FIG. 4

These effects moreover would be relatively small as compared to the effects of the lines of force set up by *V*, because these lines are greatly concentrated by the use of magnetic material whereas the horizontal lines of force are not so concentrated. Also, the magnetic bridge pieces should reduce the value of *H* in the interstices of the cage.

## CATHODE-RAY APPARATUS TERMS—*Continued from page 115*

is now rated as having a slow screen, but the intensity drops off quite rapidly to a much lower value and then phosphoresces for some time thereafter. The decay period depends somewhat on the initial excitation, so that some standard test conditions will have to be defined.

DEFLECTION SENSITIVITY. This factor is best stated in the form of volts per inch deflection for one kilovolt anode potential. In this form the circuit requirements can be mentally calculated quickly. It should be stated for both sets of plates.

MODULATION ELECTRODE, CONTROL ELECTRODE, CONTROL GRID, etc. The term should refer to that electrode that controls the brilliance of the spot without affecting its deflection sensitivity. If a numerical value is given for this factor, it is believed that the ordinary amplification factor, or "mu," provides a satisfactory designation.

NORMALITY. The writer believes that some term is needed to denote the variation with which the axes differ from 90°. Several terms might be suggested but it seems that the term NORMALITY is adequate. Likewise several systems of measurement might be suggested. The definition should take care of non-parallel plates, the effect of fields due to leads and support wires to the deflection plates, the condition where the plates are not perpendicular to each other, and in the case of magnetic focusing coils: the effect due to rotation of the jet. The following is suggested: "The normality factor is the mean value of the four angles (either acute or 90°) which the edges of an inscribed square (representing the actual field of the oscillographic diagram) make with the horizontal axis and a line drawn perpendicular with that axis. The square should have a diagonal length equal to the nominal diameter of the screen." I am sure that this wording could be improved but it represents an idea.

THRESHOLD EFFECT. This term is used in England, and by many American writers. An alternate term is ORIGIN DISTORTION. Until its causes are better known and the contributing factors known, this effect is best described with a curve, or a series of curves.

# A Plan for Centralizing Information on Special Research Instruments, Apparatus*

By RICHARD RIMBACH†

NEARLY all research activity centers about the making of measurements, and the developments of special methods and instruments, for new and better measurements, are very generally the most time consuming and expensive part of a research development. It is my hope that some of this time can be saved by a plan which I ask you to support.

There are many research workers who build instruments and apparatus for their special requirements. It is conceivable that a research worker in a medical laboratory would have need for a special instrument that had already been designed, developed and built by a worker in an oil research laboratory. No doubt the oil research worker had described his apparatus in the technical journal covering his field. The medical worker, though, cannot be expected to know of this device. Or the hypothetical conditions I have stated here may be reversed. Usually the reporter of a piece of research does not include all the details on his instrumental equipment, but in his report covers the method used and the data obtained.

Assuming that the technical report contained the information on the construction of the instruments and apparatus, the number of journals and other documents is now so heterogeneous that, even though one has access to excellent libraries, it is practically impossible to obtain and consult all the original published articles on a given subject.

Also, due to limitations in the funds which are available for publication purposes, the number of papers offered for publication is far in excess of the number which can be printed. Many papers are refused and practically all are accepted only if they are condensed to a considerable degree. Usually such condensation eliminates all reference to the method of measurement or the construction of the instrument or apparatus.

I would therefore offer to make *Instruments'* office a depository for information on research instruments and apparatus. I, therefore, appeal to you, who are on the firing line of science, to send in descriptions of the devices you have designed for your special experiments. Some one else may be saved considerable time if such information is sent in by you.

The information should consist of the paper in which you reported your investigation, plus the details about the apparatus which you left out of your scientific paper. I mean such details as dimensions, materials used and their cost, other costs involved, sensitivity, accuracy, instructions on manipulations, notes on troubles if any, limitations in range and in other respects, etc. Needless to say, a profusion of photographs and diagrams will be welcome. Nor should you waste your own note sheets of calculations of design (as distinct from calculations of measurements performed) for these exact calculations may be of permanent value to the art.

In addition to this descriptive report you will do well to append (a) notes on why the most suitable instrument already made, failed to be useful, or good enough; (b) suggestions to the next one to try the work, how to improve the design; (c) exact information on type and model of ready made units incorporated in design; and (d) significant notes on what did not work.

* From a talk "Measuring Instruments in the Sciences" before the American Institute of New York, April 24, 1935.
† Managing Editor, *Instruments*.

# The "True Direction" Aircraft Instrument Question

## Discussion of Article by A. M. Dudley in February Issue, and of Other Ideas

*To the Editor:*

Regarding Mr. Dudley's article on a "true direction" instrument for aircraft:

The idea of using the earth's vertical magnetic field to measure ground speed is very old. I recall making a report as far back as 1925—while employed by the U.S. Air Service at McCook Field—in which it was concluded that such a device is fundamentally inoperative.

*If it is assumed* (quite improperly) that the earth's magnetic field is a fixed reference system, one can devise several methods of measuring ground speed. The method described in Mr. Dudley's article is one that is not readily adaptable. A better method that I devised and actually tried out while a graduate student consisted in shooting a beam of slow-moving electrons (thermal velocities) in the direction of the line of flight of the plane. These electrons were deflected horizontally at right angle to the line of flight by the earth's vertical magnetic field and, as is well known, the amount of deflection is proportional to the velocity of the electrons with respect to the magnetic field considered as a fixed reference system. Therefore, upon the above hypothesis, the motion of the plane might be supposed to increase the electron deflection roughly proportional to its true ground speed. The deflection was arranged through special circuits to be read by a double vacuum tube bridge. However, tests of this device showed that the plane's motion produced no effect and supported the original prediction that the effect would be zero, because a magnetic field is simply a special property of space and it is *not* a fixed reference system.

There are other experiments which show definitely that no effect is to be expected. For example, arrange two copper concentric cylinders in such a manner that their axes coincide with the axis of a solenoid which produces a uniform magnetic field throughout the region between the cylinders. Insulate the two cylinders and bring out electric leads by brushes so that the cylinders and the solenoid may be rotated about their axes of symmetry. An electrometer is then connected to the cylinders through the brushes and the solenoid excited by an electric current. Now, if the cylinders are rotated at a definite speed, it will be found that a constant potential difference will exist between them, both when (a) the solenoid is stationary, and when (b) the solenoid is rotating at the same (or different) speed as the cylinders. Conversely, no potential is generated when the cylinders are not rotating, no matter what speed the solenoid is rotated. These experiments show that the magnetic field is not a fixed reference system and that the ordinary electrical engineer's conception of a line of force being a perfectly definite thing is fundamentally false.

It is, therefore, safe to state that all the available experimental data point to the impossibility of the solution of the problem by the method proposed. Further, the theory of electrodynamics predicts a real second order change, but it is too small ever to measure.

Solution of the problem by the method considered is thought to be hopeless. It *can be solved*, however, by methods of a sound but much different nature.

*Naval Research Laboratory*
*Washington, March 28, 1935*

Ross Gunn
*Technical Adviser*

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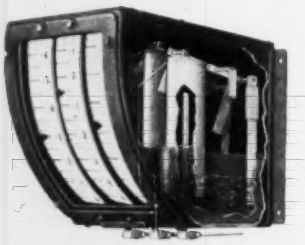

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# Metering for Special Rate Structures*

PART ONE

By PERRY A. BORDEN† and M. F. BEHAR**

## 1. Demand Measurement

### (a) General Considerations.

Electrical energy is unique among saleable commodities: Fuel, water, food stuffs, clothing, and practically all tangible requirements of man may be produced and transported during considerable periods of time, and generally stored at locations readily accessible to the ultimate consumer, whence they may be drawn upon as required. Electrical energy, however, cannot be stored* but must be produced from fuel or water power, transmitted perhaps many miles, and delivered on the consumer's premises at the instant he requires it and generally without previous notice; so that the hydraulic analogy used in introducing the subject of watthour meters falls short of conveying a true idea of conditions.

In order to show that energy consumption is not the only factor to be considered in fixing charges for electrical power, it may be well to consider a typical example. The two graphs shown in Fig. 43-1 represent plots of the load curves of two typical consumers to which a central station is supplying power. Graph *A* may be taken to represent the load of a saw mill, and *B* that of a city pumping station pumping water into a reservoir. The saw mill operates,

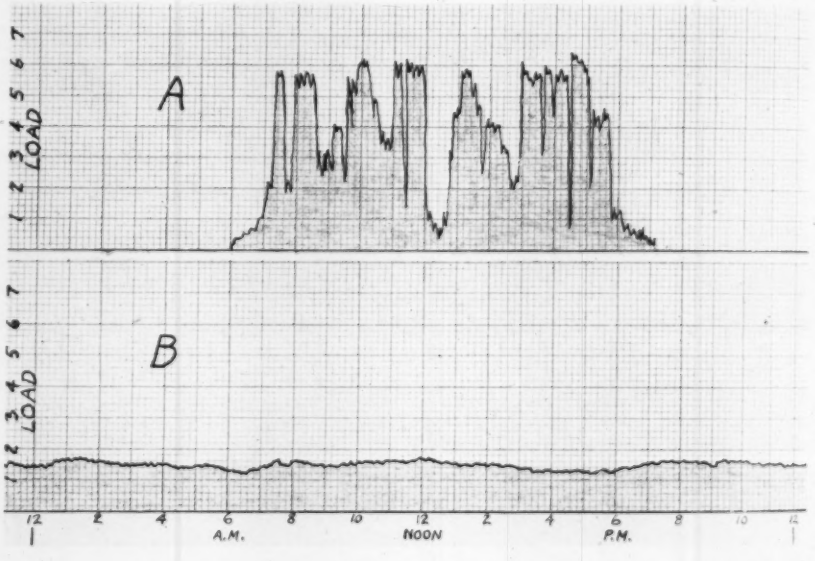


Fig. 43-1

say, nine hours a day, and only three or four months in the year. During these few months, and when big knotty logs are being cut, a large amount of power is required for a short time. Between cuts the motors run with little load. Other months of the year the mill is shut down and no power whatever is required. Consider what a task this mill is to the central station: turbines, generators, transformers, circuit breakers and lines must have reserve capacity to withstand the sudden heavy loads when logs are going through. Yet this reserve capacity is unnecessary during most of the day and idle eight or nine months of the year. In order to be ready to serve this load at instant notice

*Though the storage battery provides a reservoir from which electrical energy may be drawn, its cost is prohibitive as a means of storing considerable amounts of energy.

*Fifteenth chapter (XLIII) of Part Seven (Handbook of Industrial Electrical Measurements and Control) of Bêhar's *Manual of Instrumentation*. See editorial announcement of this series on page A7 of November 1933 *Instruments*. A complete chapter of this new handbook is published in each issue of *Instruments* throughout 1934 and 1935. Each chapter is subjected to final revision, and then set in type, shortly before its appearance in this serial form, in order to assure that the subject matter is thoroughly up-to-date. This new book is not published serially in any other periodical. Entire contents copyright. To be issued in book form on or about [illegible] 1936.

†Member A.I.E.E. **Editor, *Instruments*

it has been necessary to tie up much money in equipment which is not being used.

Compare this load with that of the pumping station, as shown at *B*, operating on a consistent schedule. Its machines are regular power consumers and utilize the central station's plant practically 24 hours a day and 365 days a year. The central station knows just what to expect all the time, and there is little worry connected with furnishing power for such a load.

Suppose that each plant consumes the same number of kilowatthours during the *year* (the graphs as plotted show each plant as consuming the same amount of energy during the *day*, and with the mill operating on the restricted seasonal schedule the divergence between the two will be much greater than so indicated). It is apparent that there must be many times the kilowatt capacity kept in reserve in the central station for the saw mill than is necessary for the pumping plant. We say that the "load factor" of the saw mill is poor and that the "load factor" of the pumping station is good. We mean that the average load of the former is a small percentage of the maximum load, while in the case of the pumping station the average load nearly equals the maximum load (See definition at end of this Section). It is obvious that the central station should not be required to supply service to the saw mill at the same price as to the pumping plant. The *operating costs* per kwhr. are approximately the same in both cases, but the *fixed charge* portion of the service cost is much greater for the saw mill. The important part played in power costs by the element of fixed charges is likely to be overlooked by those not conversant with central station economics. Actually the item of fixed charges may amount to as much as 45% of the entire cost of supply in the case of a steam plant, and as high as 85% in a hydroelectric plant.

From the above it will be apparent that the establishment of bills for electrical service solely upon a basis of kilowatthour consumption and at a definite rate per unit without consideration of load factor cannot in all cases be fair to both utility and consumer; and it is with this in view that the majority of present day power contracts take cognizance of the element of *demand*, and endeavor to incorporate *maximum* demand in the power charges. Since the item of fixed charges is usually much higher in hydroelectric power plants than in fuel-consuming plants, demand determination is more important on hydroelectric systems; and it is in those districts where water power is of relatively great importance that the measurement of demands generally reaches its highest refinement.

Since the element of demand is accepted as an index of the share of the fixed charges of electrical service to be borne by the consumer, it is well to gain a clear idea of the actual relationship between demand and the plant equipment represented. The *load capacity* of generating and transforming equipment is usually limited by the *heat developed* due to the load carried. This heating, however, is not directly proportional to the kilowatts handled by the apparatus but to a function of the voltage plus a function of the current. The iron losses in the magnetic circuits of a.-c. apparatus vary approximately as the 1.6th power of the volts, while the copper losses in the electrical circuits vary as the square of the current. The total heat developed represents the sum of these two sources. It will be appreciated that any attempt to perform an electrical measurement on this basis and incorporate the requisite precision scientific instruments in a commercial metering device would be fraught with such difficulty and expense as to render it impracticable. The limitation of prime movers is generally based on actual power developed, that of the line on the current transmitted, and that of the circuit breakers on rupturing capacity, which is probably related as nearly to volt-amperes as to any other measurable magnitude. Thus the actual electrical phenomenon whose magnitude should be taken as a true criterion of the share of the fixed charges to be borne by a consumer of electrical power is open to conjecture and may easily be made the basis of controversy. *Estimates* of demand are based usually upon installed capacity and can hardly be said to have sufficient accuracy to justify either incorporation into contracts or being accepted as a basis upon which to establish kilowatthour rates. The *metering* of consumed energy and the *estimating* of demand at the one time has been likened to measuring the length and estimating the width of a piece of property—obviously unsound from an economic standpoint. Modern practice has made it evident that quantitative determination of demand may be made with a precision sufficient for the purpose by performing measurement upon either amperes, watts or volt-amperes, according to conditions; and one or other of these magnitudes is used as the basis of measurement in all present-day demand meters.

A further consideration which enters into the measurement of demand is the element of *time*. Since heating is the prime factor in the limitation of load capacity of electrical equipment, it is possible to make a certain allowance for


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## never helped anyone

### *to discover or to invent*

The plain fact of the matter is that "inspiration" never plays a part in discovery or invention, because it always comes too late—after the correct solution idea has been conceived.

If you do not believe this, observe yourself next time you "get inspired." You probably will conclude that "inspiration" is high blood pressure and a sense of mental contentment.

No matter how fruitful it may be in the realm of ethics, philosophy or theology, inspiration has nothing to do with solving invention type problems—which are every day engineering problems, whether simple or complex.

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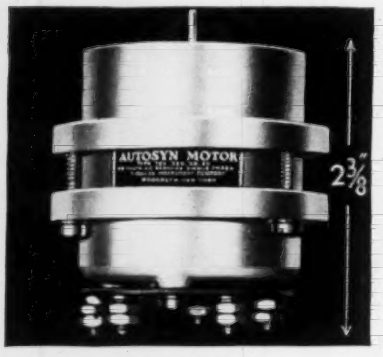


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thermal inertia, and to take cognizance of the fact that, however se[v]ere the overload, it takes time for the heat developed in the apparatus to be tra[n]smitted through its structure and bring about objectionable temperature rises. Thermal inertia is of course governed by a great variety of factors; the ultimate temperature rise of a piece of equipment under any particular load condition will be determined by many characteristics governing the rate of distribution of heat throughout the mass and the facilities for dissipating the heat as it is generated. With these facts in view it has been found necessary to employ various time intervals in the determination of demand, and to govern the selection of a particular period by the nature of the equipment and the conditions of its use. In the design of demand meters provision is made for a variety of demand intervals; and these may run from ½ minute to [1] hour, the most common being probably 10 minutes and 15 minutes.

The incorporation of demand into power contracts, and the proper weighting of the several variable magnitudes which go to make up an equitable representation of the amount to be assessed against the consumer of electrical energy, are involved in the subject of rates and rate structures—a matter of industrial economics and not within the scope of this work.

**(b) Definitions.**

As thus far considered, *demand* has been treated as a more or less abstract term. In order that it may be made the basis of quantitative measurement it is essential that it be defined as a measurable magnitude. The following definitions of demand and associated terms are reproduced from the Code for Electricity Meters.*

1. *Load Factor.* The load factor of a machine, plant or system is the ratio of the average power to the maximum power during a certain period of time. The average power is taken over a certain period of time, such as a day, a month or a year, and the maximum is taken as the average over a short interval of the maximum load within that period.

2. *Demand.* The demand for an installation or system is the load which is drawn from the source of supply at the receiving terminals, averaged over a suitable and specified interval of time. Demand is expressed in kilowatts, kilovolt-amperes, amperes or other suitable units.

3. *Maximum Demand.* The maximum demand of an installation or system is the greatest of all the demands which have occurred during the period. It is determined by measurement, according to specifications, over a prescribed time interval. In accordance with specifications, a demand may be measured by an instrument with a time lag, or an instrument integrating the load over a prescribed time interval; or the load may be determined from a sufficient number of readings of an indicating instrument, taken over the time interval.

4. *Demand Interval.* The length of the interval of time over which the demand is measured.

5. *Demand Factor.* The ratio of the maximum demand of any system or part of a system to the total connected load of the system or that part of the system under consideration.

6. *Diversity Factor.* The ratio of the sum of the maximum power demands of the subdivisions of any system or parts of a system to the maximum demand of the whole system, or of the part of the system under consideration, measured at the point of supply.

7. *Averaged Maximum Demand.* The highest average or arithmetical mean of similar demands. It may be computed from several demands on a definite number of days, either consecutive or within certain limits of time, such as a month or a year.

8. *Simultaneous or Coincident Maximum Demand.* The greatest sum of the similar demands of a number of services occurring at the same time. It may be obtained by the summation of measurements at each service or by a single measurement at the source of supply of the group.

9. *Daily, Monthly or Annual Maximum Demand.* The maximum demand which has occurred within the specified interval of time.

10. *On-Peak Maximum Demand.* The maximum demand occurring within certain designated hours, called the peak period.

11. *Off-Peak Maximum Demand.* The maximum demand occurring outside certain designated hours, called the peak period.

12. A *Demand Meter* is a device which indicates or records the demand or maximum demand.

13. An *Integrated-Demand Meter* is one which indicates or records the maximum demand obtained through integration.

14. A *Lagged Demand Meter* is one in which the indication of the maximum demand is subject to a characteristic time lag.

*A.E.S.C. Standard No. C12—1928.

## 2. Direct Determination of Demand

All the data necessary to the determination of demand over any selected time interval appear on the chart of a simple recording instrument; but the interpretation of the data in the form of elements to be incorporated in the computation of power costs is no simple matter. At the outset care must be observed to differentiate between a simple recording wattmater (or ammeter) and a recording *demand* meter. Both read in the same units, but in the former an effort is made to obtain a record of every variation which takes place in the measured load, and only such damping is introduced as will serve to eliminate fluctuations and prevent undesirable blurring of the chart record. This damping may be indeterminate in its value and subject to wide variation without materially affecting the usefulness of the instrument for its intended purpose. In the recording demand meter, on the other hand, the cross-chart speed of the recording pen or stylus is governed by definite laws, and the record becomes in itself a measure of *demand* and not necessarily of the *load* at any particular time.

The only workable method of demand determination from the charts of ordinary recording instruments lies in the selection of that portion of the curve during which the indication remains at its highest value for the duration of the selected time interval. This is known as "sustained peak." While its value cannot exceed the true maximum integrated demand, it may fall far short; and, since the speed of pen travel is usually indefinite, its "dip" at any time, in response to a momentary decrease of the load during the peak period will be an uncertain value; and any value of demand so determined will be entirely subject to the degree of damping which the particular recording instrument happens to possess at the time.

In the descriptive sections which follow, demand meters are considered under the two principal classes of Integrated Demand meters and Lagged Demand meters. The essential action of the former is to compute the average value of the load during each successive demand period, and to provide a measure of the greatest of these averages. The latter group comprises those instruments in which a measuring unit strives to indicate or record the load, but is retarded in its movements by an element having predetermined and definite characteristics.

## 3. Integrated Watt Demand—Block-interval Meters

### (a) General Principles and Classification

The majority of practical integrated-demand meters operate on the "block-interval" basis. A block-interval meter includes (a) an integrating element and (b) a timing element, the former providing a measure of the total energy passed through the circuits, and the latter dividing the lapse of time into definite intervals of predetermined duration. During the interval the integrating mechanism tends to propel a pointer, index or pen across a scale; and at the end of the interval, as determined by the timing element, the propelling mechanism is released and reset to its zero position, an indication or a graphic record being left of the maximum excursion of the index. Thus the position of the propelling device at the end of each interval represents the average energy consumption during the interval, and the position of the maximum pointer represents the greatest of these averages, or the *maximum demand* on the system.

There have been developed a large number of different demand meters operating on the block-interval basis; and it will be possible here to describe only a few of the outstanding forms in each class. In this connection it is to be understood that the relative prominence given in the descriptions is not to be taken as having any bearing on relative merits, but is for the most part based on the ease of adapting the available information to the purposes of this work. In comparing the mechanisms shown in the diagrams it will be observed that there exists a strong similarity among the essentials, and that the principal differences lie in details and in mechanical features.

Block-interval demand meters may be classified under the three heads of *printing, indicating* and *recording*, according to the manner in which the ultimate measure is exhibited. They may also be classified according to the manner with which the registers are associated with the primary measuring element, under the two heads of *direct-connected* and *electrically actuated*.

### (b) Printing Type.

One of the earliest forms of block-interval demand meter was the "Printometer," placed on the market about 1910 by the Minerallac Electric Co. of Chicago. The operation of this device was based on the idea of providing a permanent record of watthour meter readings taken at uniform time intervals. This meter was announced in two forms, one in which the readings advanced continuously with the meter register and another in which the reading at the end of each interval represented the actual consumption during that interval.


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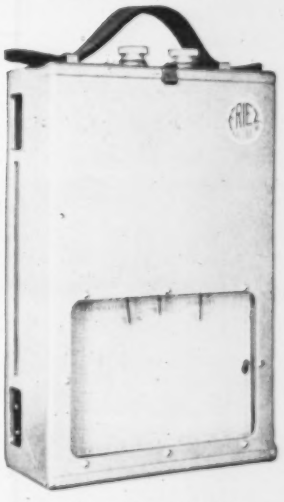

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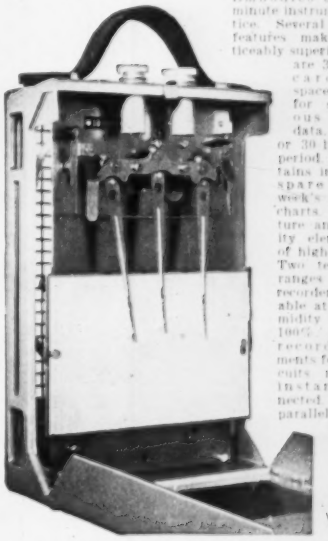

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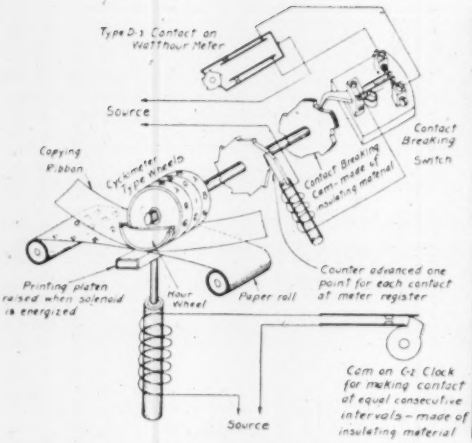
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Fig. 43-2

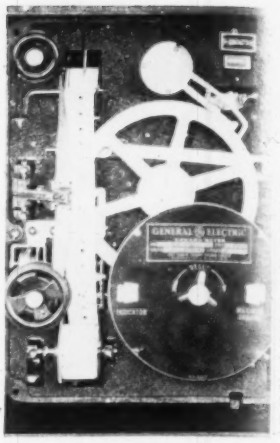


Fig. 43-3 Fig. 43-4

The "Printometer" survives in the General Electric Co.'s "Type P" and "Type PD," corresponding to the two forms mentioned above. Fig. 43-2 shows a diagram of the mechanical and electrical essentials of the Type P instrument, and the latest form of Type PD is shown in Fig. 43-3. The operation will be apparent from a casual inspection of the diagram. A set of type-wheels operating as a cyclometer dial are progressively advanced by an electromagnet receiving impulses from a contact in the watthour meter. A movable platen is periodically energized by another magnet, receiving impulses from a clock, bringing a paper strip into engagement with the type-wheels and printing thereon a number representing the position of the watthour meter register. A portion of record tape from a 15-minute meter of this type is shown in Fig. 43-4. These two meters find uses in the determination of demand and in the provision of other informative data in the operation of large generating stations.

**(c) Direct-connected Indicating Types.**

As typical of the direct-connected indicating block-interval demand meters the Westinghouse "Type OB" will first be briefly described. This is made in the form of a removable register, and may be fitted to any of the Westinghouse meters in the "OB" class. Fig. 43-5 is a schematic diagram of the mechanism. The gearing of the register consists essentially of three trains: the watthour meter gearing, the demand pointer gearing and the motor gearing. The main spindle of the watthour meter is shown as carrying two worms (actually these

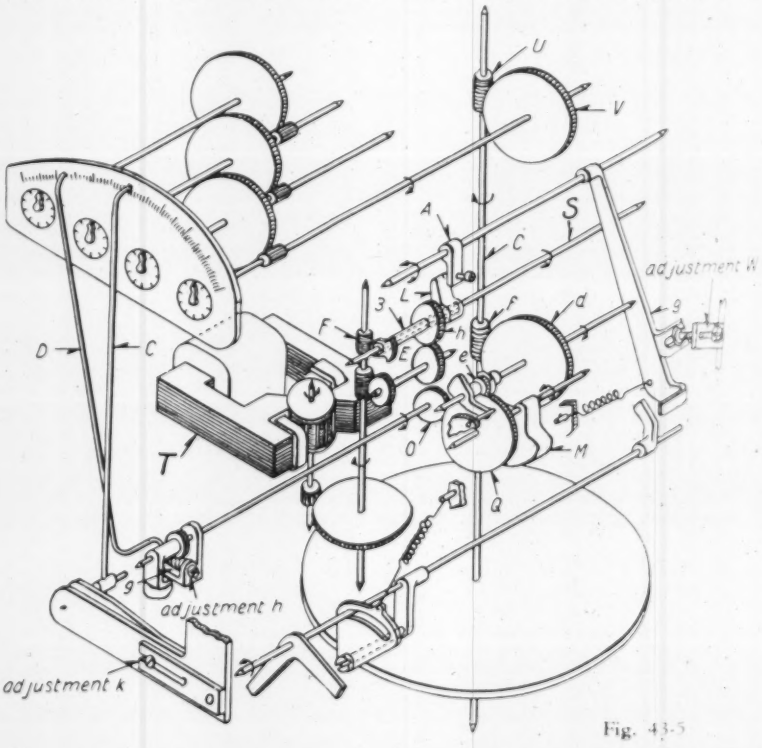



Fig. 43-5

are mounted on the second shaft of the register). The worm $U$ drives the watthour pointers through the worm wheel $V$ in the ordinary manner. The lower worm $F$ drives a worm-wheel $d$, and, through gears $e$, $Q$ and $O$, the main shaft of the demand pointer (or pusher) $D$. One bearing of the shaft which carries the worm-wheel $d$ rests in a lever $g$, which permits the worm gearing to be demeshed, allowing pointer $D$ to be returned to zero by action of weight $M$ in the gear train. The maximum pointer $C$ is advanced by pointer $D$ and is held by friction in the position of maximum deflection until manually reset.

The length of the time interval is determined by the motor gearing. The speed of synchronous motor $T$ is reduced by suitable gearing to give one revolution of gear $h$ in the time interval for which the register is set (say 15 minutes or 30 minutes). This gear is carried by sleeve 3 and runs free on the shaft $S$. A worm-gear sector $E$ and a cam member $L$ are fixed to shaft $S$ and a pin driven by gear $h$ slowly rotates the gear sector until it engages worm $F$ on the high-speed motor shaft. The gear sector passes rapidly through worm $F$, the motion of the cam being transmitted to the lever $g$ and demeshing the worm-wheel $d$ from the worm $f$, allowing ample time for pointer $D$ to return to zero. The time of demeshing approximates 3 seconds, which is negligible as compared with the time interval of the register. Fig. 43-6 shows the face and dials of this register.

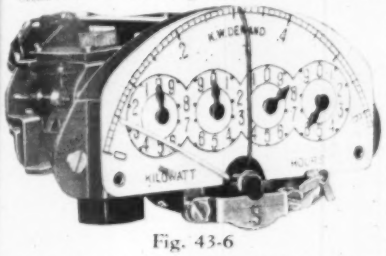


Fig. 43-6

Another interesting demand register of the direct connected indicating type is the Sangamo "Type HB," which is available as an attachment to the standard lines of watthour meters manufactured by that company. Fig. 43-7 is a diagram of this register, and its operation will be understood from the following description:

The register 3 is driven through the usual train of gearing from the watthour meter disk 1. Shaft 4, through gears, also drives shaft 28 which carries pusher arm 23. This pusher arm rotates at a speed proportional to the rate of energy consumption, and, as it travels across the scale, it pushes the indicating sweep hand 25. The power from the watthour meter is transmitted through a friction clutch that couples gear 6 to shaft 28.

The resetting mechanism, which converts this indicator into a maximum demand indicator, is operated by synchronous motor 18, which through worm reduction and gears, operates two cams 16 and 17. Cam 16, through double reduction 30 and 22, 32 and 33, operates at one speed, while cam 17 operates sixteen times faster on intervals greater than five minutes, while on five-minute intervals, 50 or 60 cycles and all 25 cycle fifteen-minute intervals or less, the ratio is 4 to 1. On the face of cam 16 rides a pin 11, which is carried on an arm 12 and held in positive contact by a cantilever spring 13. When cam 16 is in such position that notch 34 is below the pin, then the pin 11 rides on cam 17, and when the low side of cam 17 comes under the pin, it drops into the notch. Then through pin 10, arm 9 which carries a toothed sector, is pushed down and, through pinion 8, rotates pusher arm 23 back to zero. The power from cantilever spring 13, pushing through pin 10 or arm 9, is sufficient to overcome the friction clutch and

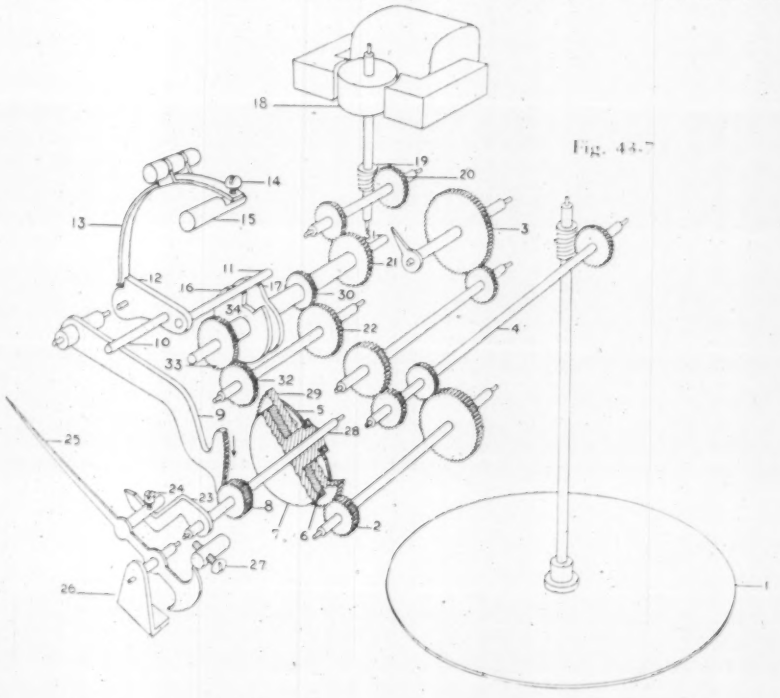
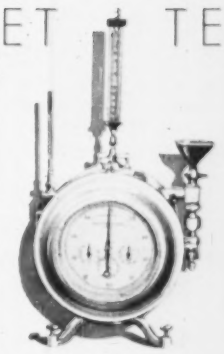


Fig. 43-7

WET TEST



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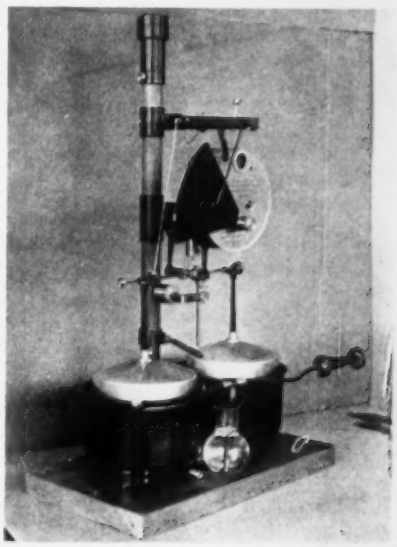

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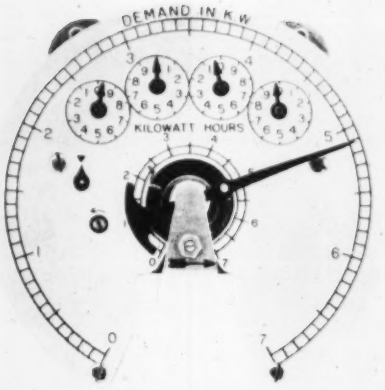



Fig. 4 8

return the pusher arm to zero, the zero point being determined by adjustment screw 2 which acts as a stop. This operation is performed quickly and cam 17 then raises pin 11 which, by that time, is picked up by cam 16 and carried until the next interval occurs.

The normal rotation of shaft 28, by the watthour meter disk, returns arm 9 to position ready for the next resetting. The indicating hand 25, due to friction in spring bearing 26, remains in whatever position the pusher arm leaves it.

Coordination between pusher arm 23 and indicating pointer 25 is attained by means of adjustment screw 24. The tension of cantilever spring 13 is adjusted by means of screw 14.

Fig. 43-8 is a view of the face of the Sangamo "HB" register.

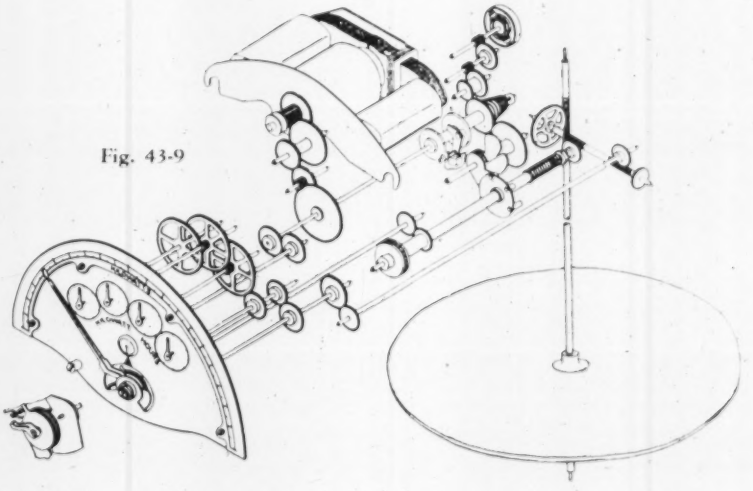


Fig. 43-9

The General Electric Company's "M-20" demand register is diagrammatically shown in Fig. 43-9. Its operation is substantially the same as that of the two types described above. A view of the face of the register is shown in Fig. 43-10. This device has been developed and is available in a cumulative form, known as the "M-21," in which the demand is read on a set of dials rather than from the indication of a single pointer on a scale. At the time of reading the meter the demand pointer is reset to zero, which causes the demand dials to rotate an amount corresponding to the value of the maximum demand. The difference between the readings thus appearing and the previous reading from these dials is the maximum demand. This form of register possesses the feature that the dial indication of maximum demand for each reading is automatically added to the previous demands, so that a cumulative indication of these demands is available.

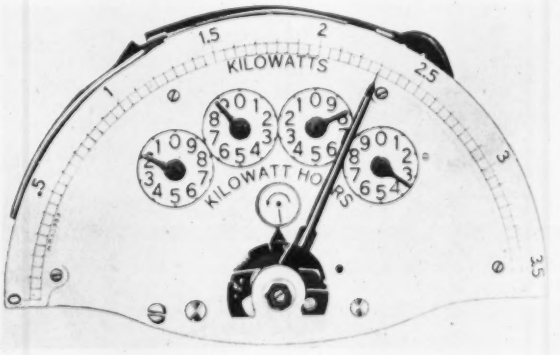
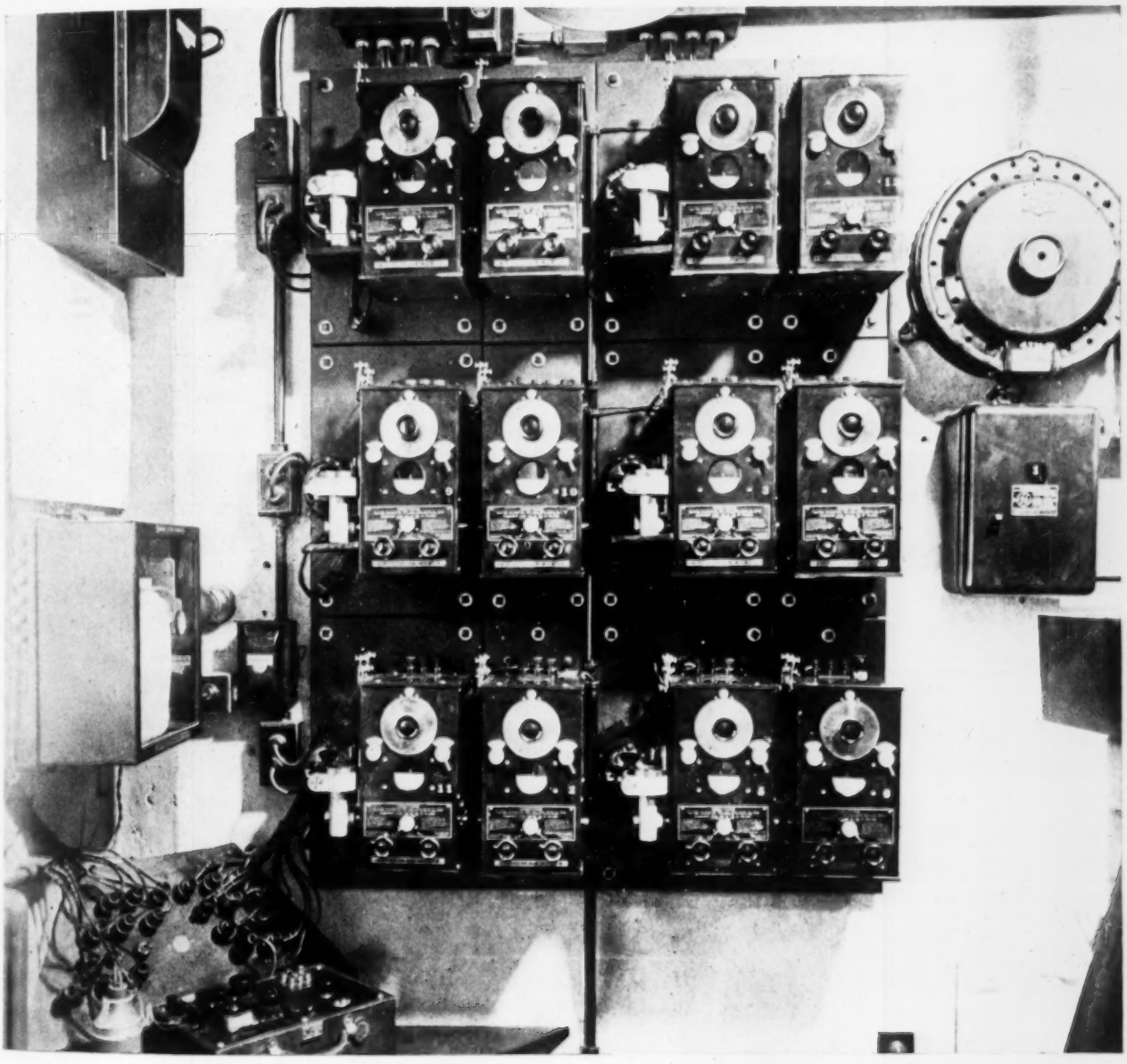



Fig. 43-10

# INSPECTION and TESTING



CREEP TEST CONTROL EQUIPMENT AT BATTELLE MEMORIAL INSTITUTE

*(Courtesy The Foxboro Co.)*

# The Measurement of Creep of Metals

By EVAN A. DAVIS*

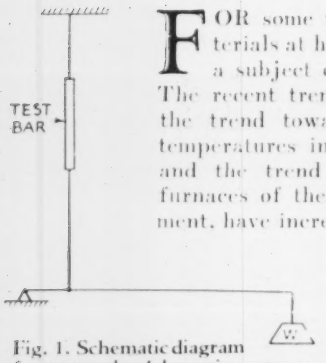



Fig. 1. Schematic diagram of constant-load long-time creep testing machine.

FOR some time the properties of materials at high temperatures have been a subject of interest to the engineer. The recent trends in industry, especially the trend toward higher pressures and temperatures in our steam power plants, and the trend toward larger industrial furnaces of the type used for heat treatment, have increased the necessity of foretelling what will happen to a material under stress at these high temperatures over a period of years corresponding to the service life of the apparatus in question. At various research laboratories, both in this country and in Europe, a large number of investigations have been made of the behavior of metals at temperatures up to about 1000°F. These tests have shown that many of the ordinary materials are not suitable for such applications, and the results have led metallurgists to develop special alloys to be used for high-temperature work. It is not the object of this paper to review these investigations in detail, but to describe the mechanical methods used in obtaining the necessary data on strength.

It is a well-known fact that the ductility of a metal increases with increasing temperatures. There are exceptions to this rule, but in most cases it is true for the range of temperatures used in present-day machine design, and it seems reasonable to expect that the ductility increases right up to the melting point. Under these conditions of elevated temperature it may be expected also that metals subject to stress will change their dimensions. This change in dimensions takes place so slowly that it requires the use of a delicate extensometer for its observation.

It has been found that the rate of deformation of the material due to this flowing at a given temperature depends upon the stress and upon the material. For any given material the rate of deformation will increase as the stress increases. The amount that the material deforms during its service life may or may not be a matter of importance. This refers, of course, to small deformations and not to deformations which would lead to rupture. For example, a boiler tube might increase in diameter by one or two percent while in service without causing any trouble or damage, but a turbine blade which might be expected to last twice as long as the boiler tube has only a small clearance to begin with and its maximum deformation must not exceed a small fraction of one percent after years of service. The design engineer, then, in choosing a working stress for a high-temperature application, must meet two conditions: first, he must choose a stress such that the material will withstand the load and, second, he must choose a stress such that the total deformation at the end of the expected life of the machine will be less than some given allowable deformation. Quite often a much lower working stress is required to meet the second condition than the first. This slow deformation, which takes place below the yield point as determined by the ordinary tensile test, is what is known as the "creep" of the metal.

The remainder of this paper will deal with two general tests used in the measurement of creep. These tests are the constant-load long-time creep test and the constant-velocity or strain-rate test.

Of these two tests the first has been used for several years for obtaining data for design purposes. The set-up for this long-time test, shown rather schematically in Fig. 1, has been described variously in detail.[1] In this test, as can be seen from the sketch, the test piece is suspended from a rigid frame and loaded through a system of levers with a constant load. The extension of the test specimen is measured with a special extensometer which must be constructed so that it will operate accurately in the high temperature of the furnace.

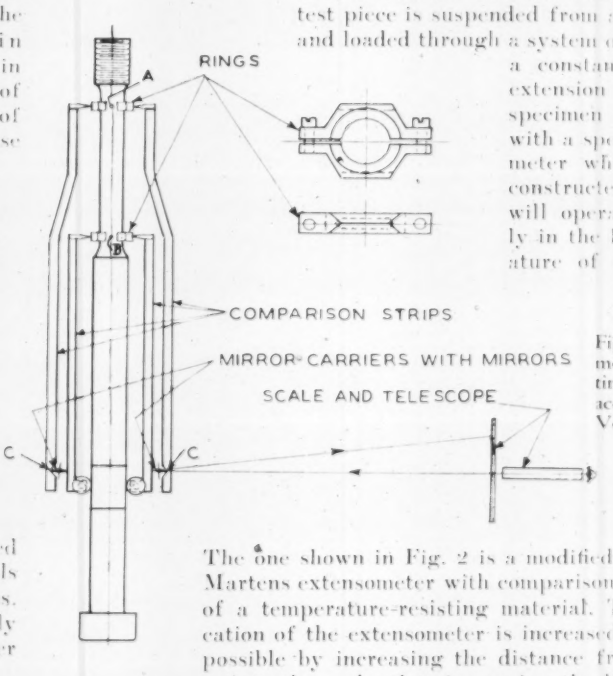



Fig. 2. Arrangement for long-time tensile test according to Martens-Le Chatelier-Le Verrier-Le Chatelier-Le Chatelier-Le Chatel

ing and controlling the temperature. Another method consists of placing a resistance (platinum wire) in the furnace next to the test bar and using the change in resistance as an indication of the temperature. Still another method is to place a metal rod in the furnace and to use the thermal expansion of this bar to measure the temperature. These devices are generally used to cut in or out a resistor in series with the furnace windings. This resistor has a value about one-tenth that of the resistance of the furnace winding so that the current through the furnace is either 5% higher or 5% lower than the average current required to keep the temperature constant.

In this type of test, which usually lasts about three to four months, the elongations are measured at intervals of about a week. The unit elongations are then plotted as a function of time as shown in Fig. 4. The speed of deformation is then measured by determining the slope of the curves. The slope of some creep curves seems to decrease continually as long as the test lasts while other curves seem to approach a constant slope. Still other curves at the higher stresses reach an inflection point as at A, Fig. 4, where the slope stops decreasing and starts to increase. Such a piece will continue to deform at an increasing rate until it finally ruptures.

The value of these curves to the design engineer depends upon his ability to interpret them. In order that the tests will not last for an extremely long time they are run at stresses higher than the expected working stresses. To arrive at the final working stress, then, the engineer must be able to extrapolate these curves to lower stresses and to much longer time values.

In the constant-load test described above it can be seen that the velocity of deformation is dependent upon the stress at which the test is made. This relation has led to the idea of making a test such that the velocity would be kept constant and the stress allowed to adjust itself accordingly. This is the constant strain-rate test, and can be made by keeping one of the heads of a testing machine in a fixed position while moving the other head with a constant rate. This can be done on an ordinary testing machine of the screw type, provided that some means are taken to keep the beam in the balanced position at all times. The writer has run some tests of this type on a modified Amsler hydraulic testing machine similar to that shown in the sketch, Fig. 3. This machine has been designed by A. Nadai and W. O. Richmond so that the hydraulic head can be used to measure the load while the test bar is being stretched by a screw drive attached to the lower head. This screw drive is connected through various speed reducers to a constant speed motor. By inserting different speed reducers it is possible to vary the velocity over a range of 1000 to 1. In these tests the deformations were large and could not be measured by an extensometer of the Martens or Huggenberger type. Instead two telescopes containing micrometers were focused (through small windows in the furnace) on scratches marking the gage length of the

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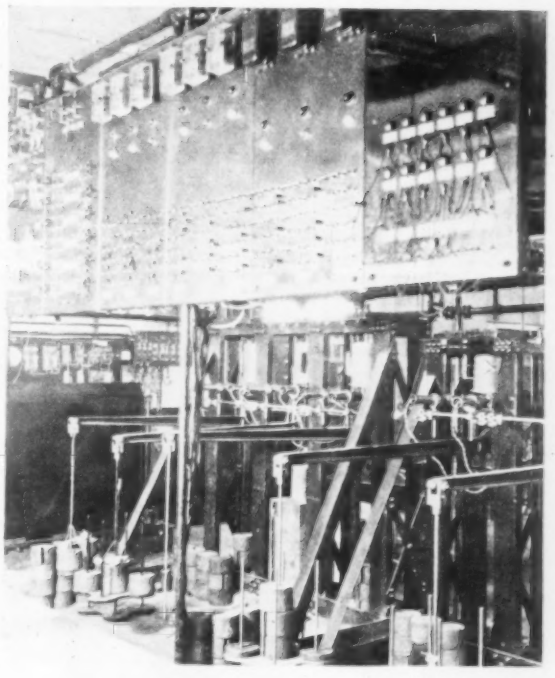

Creep test and control equipment at Westinghouse Electric & Mfg. Co., East Pittsburgh Research Laboratories.

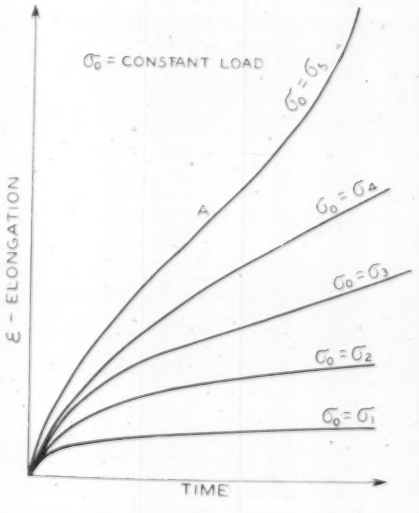


Fig. 4. Typical long-time constant-temperature creep test curves (according to McVetty).

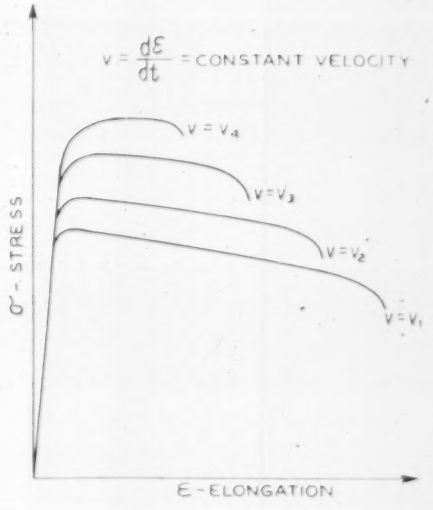


Fig. 5. Typical stress-strain curves obtained from constant strain-rate tests.

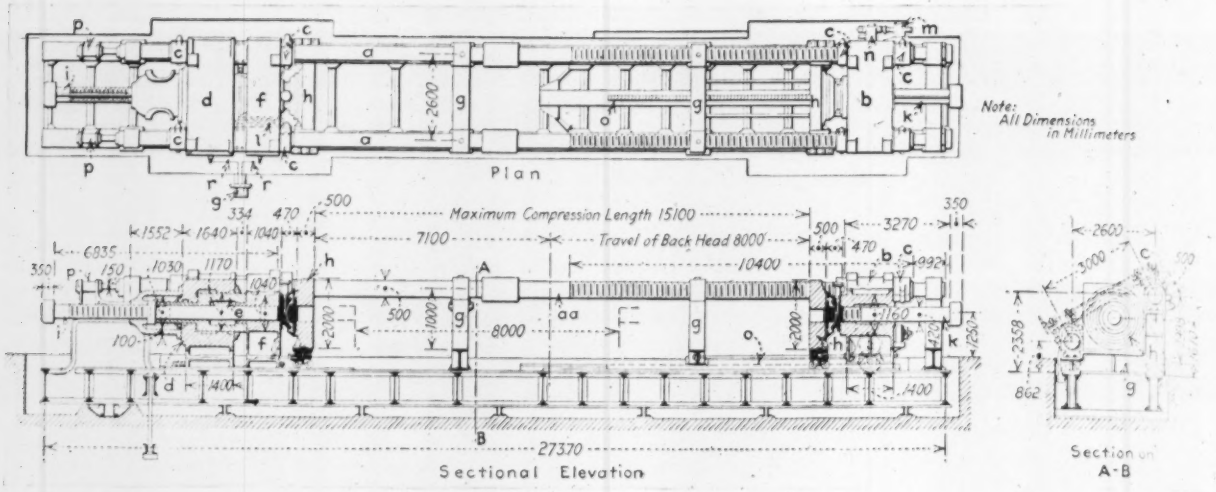


Fig. 36. The Large Testing Machine at Grosse Lichterfelde, Berlin, Germany, Built About 1910

# Materials Testing Machines

**An Account of Their Development, with Special Reference to the Tension-Compression-Transverse Group**

By C. H. GIBBONS*

PART SEVEN

The failure of the Quebec Bridge, August 29, 1907, due to the failure of a detail in a large compression member, spurred the construction in the United States, and probably to some extent in Europe, of large-capacity testing machines in which full-size structural members might be tested to destruction.

About 1910, there were constructed three large testing machines, namely, the 6,600,000-lb. compression, 3,300,000-lb. tension machine at Grosse Lichterfelde;[75] the 10,000,000-lb. compression Olsen,[76] and the 2,300,000-lb. compression 1,150,000-lb. tension Emery,[77] both of the latter at the National Bureau of Standards, Washington, D. C. Each of these machines deserve a place as items in the historical development of testing machines.

The great testing machine at Grosse Lichterfelde, Berlin, Germany (Fig. 36), is a horizontal one, having a capacity in compression of 3,000 metric tons (6,600,000 lbs.) and accepting specimens up to 49 feet in length, and having a maximum transverse dimension of 98″. The compression heads are about 79″ square. In tension, its capacity is 1,500 metric tons and it accepts specimens 26 to 42½ feet in length. It was designed by Dr. Seifert, President of the German association of bridge builders, and built by Haniel and Lueg, Düsseldorf. It is about 95 feet, overall, in length and 14½ feet wide. Its longitudinal axis is 50″ above the floor level and the hydraulic load cylinder is 46″ in diameter, weighing 88,000 lbs. The ram is cup-leather packed. The screws are 19″ in diameter and 82 feet long, and are in two sections each. Clear space between the screws is 98″. Load on the specimen is evaluated from precision manometer readings[5] of pressure in the main load cylinder, pressures being respectively for tension and compression about 3,000 and 6,000 lbs. in.$^2$

The 10,000,000 lb. (compression only) Olsen,[76] now at the National Bureau of Standards at Washington, D. C., was originally (1910) installed in Pittsburgh, Pa., at the Arsenal Grounds. (Fig. 37) It was moved to Washington about 1921 and is installed near the great Emery Universal in the basement of the Bureau of Standards Building. It was designed and built to be 70 feet high above the floor level and was about 8 feet below. When installed in Washington, however, due to the lack of head room, the upper portion of each of the

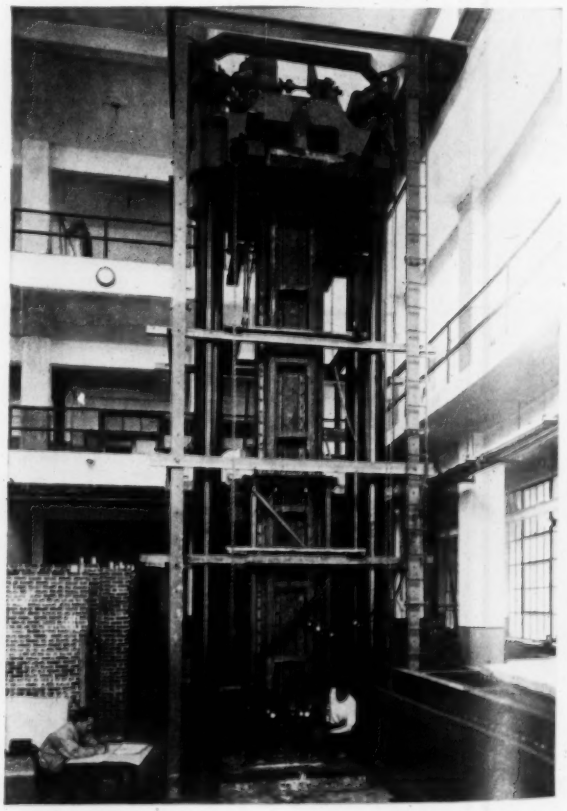

Fig. 37. The 10,000,000 lb. Olsen Machine Originally Installed at Pittsburgh, But Now at the Bureau of Standards, Washington, D. C. (Courtesy National Bureau of Standards)

*Baldwin Southwark Corp., Philadelphia, Pa.

[74] *Engineering News*, Vol. 62, 1909, pages 377, 386.

[75] *Zeitschrift des Vereines deutscher Ingenieure*, 1912, page 479; *Engineering News*, May 2, 1912; *Stahl und Eisen*, March 7, 1912; *American Machinist*, Vol. 39, No. 16, page 656.

[76] *Engineering Record*, Vol. 59, No. 6, February 6, 1909, page 164.

[77] *American Machinist*, January 2nd and 9th, 1913.

13½" diameter screws (each 72' 2" long and in two sections) was removed. The machine today, therefore, accommodates specimens up to 72" square and about 30 feet in height maximum. The top head, which weighs nearly 50,000 lbs., is movable by means of a motor mounted on the head, gearing and large nuts on the four screws, and has a maximum speed of about 10" /min. The main ram is 50" in diameter with 24" stroke and is supplied with fluid under pressure from a motor-driven triplex pump. Testing speeds vary from ½" /min. to 1/60" /min. by variation in pump speed. Communicating with the main cylinder is a cylinder with a ram (5 9/16" diam.) having about 1/80 the area of the main ram.

This cylinder has its diaphragm between the fluid under pressure and the ram and the necessary resistance to the load is supplied by a lever and poise system which measures the pressure in the main cylinder. Recently this weighing system has been supplemented by a Bourdon tube gage assembly having several gages and measuring pressure with equal accuracy and with much greater convenience in manipulation.

In 1909, while the 10,000,000-lb. Olsen was being built, a bill was introduced into Congress appropriating nearly $2,000,000 for a horizontal Emery Testing Machine of 22,000,000 lbs. capacity in compression and 11,000,000 lbs. in tension to accept specimens up to 100 feet in length. This machine, by many times the largest ever seriously considered, had been designed by Emery and the drawings are available still. While the bill never received Congressional approval, Congress did approve the construction of a horizontal Emery universal machine of 2,300,000 lbs. capacity in compression and half that value in tension to accept compression specimens up to 33' 1¾" in length and 54" diameter, and tension specimens to 34' 4" after straining. (Fig. 38) At the same time to provide a machine of greater convenience and ease of haadling for much of the routine testing necessary in the work of the National Bureau of Standards, Congress approved, also, the construction of a horizontal Emery universal of 230,000 lbs. capacity, both in tension and in compression. The construction is essentially the same as that of the larger machine and its pressure fluid supply comes from the same system as that supplying the larger machine.[77]

In essential, these machines are the same as the Watertown machine previously described. In details there are many improvements. Whereas the Watertown machine has four hydraulic supports which are used both for tension and compression weighing, the 2,300,000-lb. Emery has three supports, two of which are in parallel for compression weighing and one of which is for tension loading. Correspondingly, there are three supports or "chambers" in the weighing scale, two for compression and one for tension weighing.

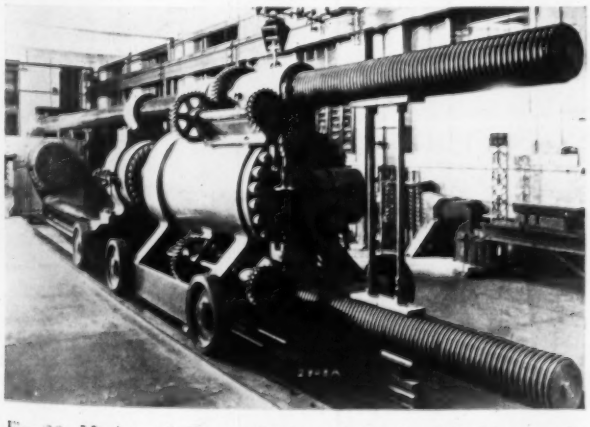

Fig. 38. Horizontal Emery Universal Testing Machine at the Bureau of Standards, Washington, D. C. (Courtesy National Bureau of Standards)

The construction of the hydraulic support for the Watertown machine had been such that the diaphragm itself had bridged the gap between ring and column without auxiliary support. Maintenance of this narrow annular ring had always been a problem at Watertown with periodic replacement of the diaphragm a necessity. Therefore, in the construction of the National Bureau of Standards' machines, a bridge ring across this gap was introduced. This ring serves to center and maintain

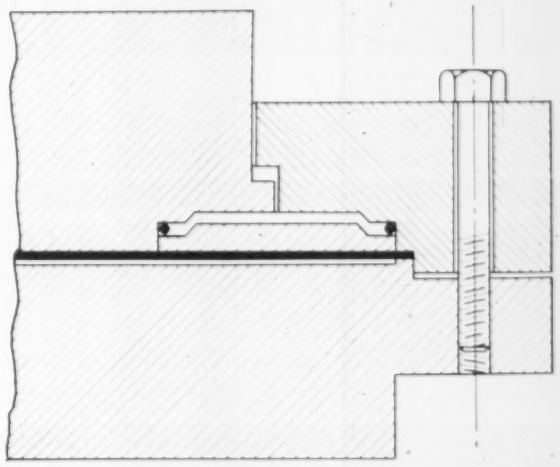

Fig. 39. Sectional View of the Emery Hydraulic Weighing Capsule.

central the column or "piston." In service this ring changes from a plane surface to one slightly saucer shaped. Of course, calibration effectually eliminates any inaccuracy in weighing which might be introduced. This ring also effectually eliminates the periodic failure of the diaphragm. (Fig. 39)

The screws of the machine are 12" in diameter and are threaded for 30 feet of their 50-foot length. The compression heads are 36" in diameter, but there is a clear space between the two screws of approximately 51". The piston is 32⅛" in diameter and the piston rod is 22" in diameter. The hydraulic power supply consists of a motor driven 1⅛" × 8" triplex pump with three special accumulators for the two testing machines. Pressures available for the large machine are 3,170, 2,160, 1,280 and 280 lbs./in.$^2$, while for the small machine 2,500 and 280 lbs./in.$^2$ are supplied.

It is of interest to note that the total ratio of the large machine is 2,000,000 to 1. That is, a 1" movement at the end of the fourth indicating lever means a movement of one-half of one-millionth of an inch in the specimen. It does not follow, of course, that 1 lb. in the scale balances 2,000,000 lbs. on the specimen, as the balancing weights are introduced at points where the ratio is much less.

Calibration was a long and tedious process, but in its essentials was the same as that described in connection with the Watertown machine.

In the last decade there have been built three large testing machines; two of which are worthy of note because of size, and the third because of its incorporation of principles of testing machine designs which were used early in testing machine development, but which had been practically discarded for nearly 40 years.

The first of these is the 2,500,000-lb. Riehle built for John Roebling's Sons, Trenton, N. J. This is a vertical, universal of the three rotating, reversed screw lever-and-

poise type and will accept specimens in compression up to about 25 feet long and tension specimens up to about 23 feet long. (Fig. 40) The straining system is mechanical and the weighing system is that which was then

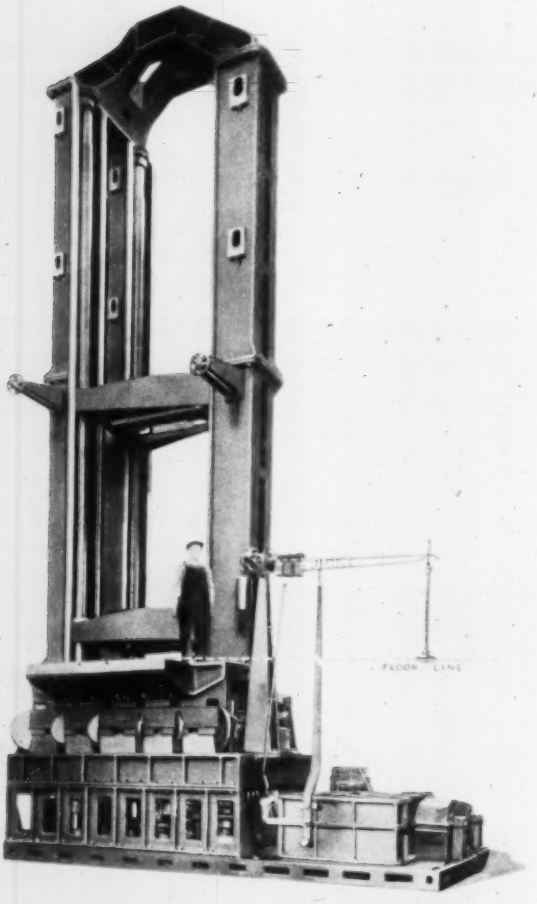


Fig. 40. The Riehle Machine of 2,500,000 lbs. Capacity Built for John Roebling's Sons. (Courtesy Riehle Testing Machine Division, American Machine and Metals, Inc.)

customary, namely, lever-and-poise. At the time it was built it was the world's largest, employing mechanical load producing and load weighing devices. This machine has a clear distance of 6′ 3″ between the screws and stands 33′ 3″ above the floor level. It is approximately 21 feet right to left and 13 feet front to back.

*To be Continued*

## CREEP OF METALS

*Continued from page 129*

test bar, and the movements of these scratches were recorded as a measure of the elongation. The temperature was measured by thermocouples pressed against the test piece by springs as described above.

The type of stress-strain curves obtained in a set of constant strain-rate tests is shown in Fig. 5. It can be seen that for a given velocity or strain-rate the curves bend gradually into more or less horizontal curves after the yield stress has been reached. If the velocity is decreased the curves are lowered and the corresponding yield stresses are decreased. It requires, however, a comparatively large change in the strain-rate to make a noticeable change in the strength of the bar. For example, in the tests of the writer mentioned above, the ultimate strength was decreased only 12% when the velocity was reduced to 1/25 of its former value. A study of these curves seems to indicate that the yield stress and ultimate strength can be made extremely low by simply reducing the speed of deformation to sufficiently low value. However, in order to bring the yield stress down into the range of working stresses, it would be necessary to reduce the rate of strain to such a low value that several years might be required to obtain one percent deformation.

For several years research engineers have been studying the relation between stress and the rate of strain and have been trying to express this relation mathematically. At ordinary room temperatures, tests by Ludwik[2] have shown that for a given strain and for varying velocities the yield stress $\sigma$ is given by

$$\sigma = \sigma_1 + \sigma_2 \ln \left( \frac{v}{v_0} \right)$$

in which $\sigma$ = yield stress

$$v = \frac{d\varepsilon}{dt} = \text{rate of strain}$$

and $\sigma_1$, $\sigma_2$ and $v_0$ are constants.

A similar expression was developed by Prandtl[3] from a theoretical standpoint and has been checked by Deutler[4] who has found that the law agrees with test results on iron and copper at normal temperatures, while Brinkman[5] has checked it by making impact tests on copper also at room temperatures.

For elevated temperatures the law connecting stress and the rate of strain has not yet been accurately established, although a large amount of very valuable experimental observations have become available during the past years. In order to use this experimental data a method of extrapolation has been developed by McVetty[6] in which the asymptotes of the creep curves are used for predicting the deformation at some future time. It seems worthy of mention that the relation of stress to rate of strain at high temperatures is one of the problems confronting the engineers in this field at the present time and that progress along this line will surely result from a deeper study and a better understanding of the whole phenomena of creep.

The writer wishes to acknowledge his indebtedness to Dr. A. Nadai and to Mr. P. G. McVetty for their valuable instruction and information concerning the properties of metals at high temperatures and to the Westinghouse Research Laboratories for permission to publish this paper.

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P. G. McVetty. Working Stresses for High Temperature Service. *Mechanical Engineering*, Vol. 56, March 1934, pages 149-158.

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# NEW INSTRUMENTS

In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions.

When writing to manufacturers directly, please mention this department as your source of information.

Or write to Information Section, Instruments Publishing Company.

## Low-pressure or Draft Indicating Controllers

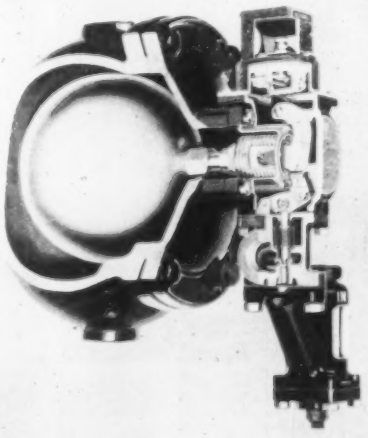
Designed for applications requiring close control of non-pulsating pressures below 1" water (above or below atmospheric pressure) "Types 1.210-1 and 1.910-1 Static Pressure Regulators" have been brought out by the Minneapolis-Honeywell Regulator Co. for controlling (1) static head as in air distribution systems, (2) draft or (3) differential pressure. Primary element is an oil-sealed inverted bell, from which a push-rod extends into control head (shown here with cover removed) where the push-rod motion either actuates electric contacts (in "L 210-1") or changes the setting of a resistor (in "L 910-1"). Control head cover is provided with a window for viewing the setting scale which serves also as a calibrated indicating scale. In addition to the usual control-point setting, an adjustment for the value of the operating differential is provided in both the contacting and the modulating types. By removing the spring of this differential-setting mechanism, extreme sensitiveness is obtained.

## Supervisory System

Operating over 2 wires and including devices used in larger supervisory systems, a new 5-point automatic supervisory system available from the General Electric Co. provides for the complete supervision of 5-substation units. It permits opening and closing of circuit breakers with indication of their position; starting and stopping of machines with indication of their conditions; raising and lowering of speed, voltage, or gates, and obtaining of instrument readings; and it allows telephone conversations and calling. Dispatcher's office equipment consists of a control key, indicating lamps, and supervisory devices for sending selection and control impulses, and for indicating the positions of the various supervised units completely assembled in a desk cabinet and requiring connection of only 2 line wires and 2 battery wires for complete installation. Substation equipment (supervisory devices which transmit control impulses to auxiliary control relays and send back checking and indicating impulses to dispatcher's office) is assembled in a case designed for panel mounting and is equipped with numbered terminals for connecting 2 battery wires, 2 line wires, and breaker control and indication circuits.

## Boiler Water Level Control and Cut-off

McDonnell & Miller announce a complete line of improved feed-water cut-offs, automatic level regulators and combination controls, embodying numerous new features some said to be exclusive which may be summarized as follows: (1) Feed valve isolated from heat of float chamber so that water surrounding it cannot reach temperature at which lime and scale form (patent No. 1,934,186), preventing sticking of feed valve. (2) Water fed independently of float chamber not into it. (3) Valve toggle compartment sealed away from float chamber and feed valve by two Sylphon bellows, doing away with stuffing boxes and packing. (4) Toggle and linkage to multiply valve-closing force. (5) Main lever pivoted in center of bellows to prevent undue distortion of bellows. (6) Cam-and-roller "straight-thrust" valve action instead of conventional off-center thrust. (7) Large strainer factory-mounted ahead of valve keeps out pipe dope, cuttings, etc. Illustration shows "No. 51-2" combined safety feeder and low-water cut-off suitable for automatically-fired boilers $>5000$ ft.$^2$ and pressure $<25$ lbs./in.$^2$

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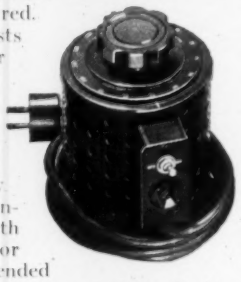
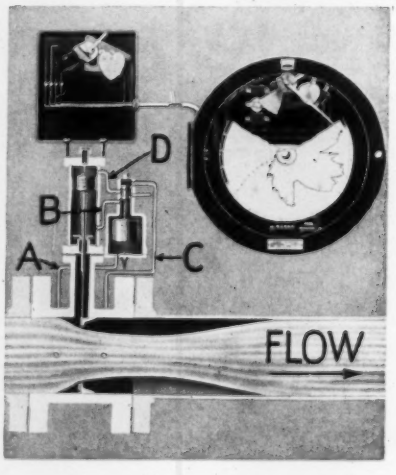
## 230-Volt "Variacs"

In many applications of the General Radio Co.'s "Variac" adjustable transformers, models for use either on 230-volt circuits or on 115-volt lines for output voltages above 135 volts are required. To meet requests for units smaller than the 2-kva Type 100, there have been developed two models, mechanically identical and interchangeable with Types 200-CU or 200-CM, and intended for the following uses: on 230-volt inputs to deliver output voltages continuously adjustable from 0 to 270 volts; on 230-volt input circuits to furnish output voltages from 0 to 230 volts with slightly higher wattage ratings; on 115-volt circuits to deliver output voltages from 0 to 270 volts. Dials read directly in output voltage with an accuracy of ±2% for the 270-volt output.



## Re-designed Flowmeters

Several new models of the Isometer—a gate type area meter—are announced by the Elgin Softener Corp., the expanded line of meters now including three forms of primary elements or "actuators" and a complete choice of remote indicating, recording, integrating and combination instruments. In common with all other flowmeters which use a straight-line flow through a varying orifice with a fixed differential, the Isometer is characterized by a wide measuring range, extending down to flow rates as low as 2½% of rated capacity. A new form of primary element, employing the pilot-valve principle for positioning the gate, has been added to the lever form (see *Instruments*, Oct. 1932, page 246) and to the dead-weight form (see *Instruments*, Dec. 1933, pages 226-227). As shown in the illustration, the weight which determines the fixed differential of 5 lbs./in.² is direct-connected to the pilot slide. Employment of this relay principle stabilizes operation so that certain fluctuating flows can be metered. Available sizes range from 1" to 12"; maximum steam pressure which can be handled in 250 lbs./in.²; maximum steam capacity with 5 lb. pressure drop is 126,000 lbs./hr.; with 10-lb. pressure loss 126,000 lbs./hr.

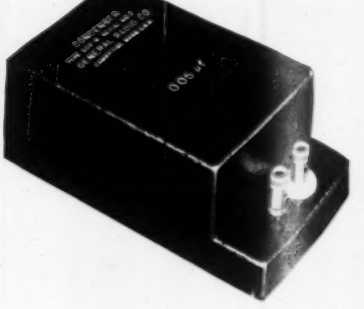



## Vapor-pressure Recorder

Although gasolines are graded on a vapor-pressure basis, the usual stabilizer unit lacks an indicator of the vapor-pressure of the product being processed; the recording of column pressures and temperatures, the metering of quantity of stock, and the correlating of laboratory tests (which may be hours or weeks old) do not suffice to enable even the best operator to produce at all times a product that will meet rigid specifications. A solution of this problem by F. L. Kallam, of Industrial Engineers, Inc., takes the form of an apparatus through which a continuous sample passes from the gasoline plant (negligible time lag), through a water bath maintained at 100±0.07°F. and into a pressure-measuring chamber in communication with an absolute-pressure recorder. The standard refinery type developed by Industrial Engineers, Inc. (illustrated) is suitable for recording vapor pressures up to 20 lbs./in.² abs. at 100°F. Exclusive manufacturing and sales rights have been assigned to the C. J. Tagliabue Mfg. Co. A development program is under way whereby this apparatus will be adapted for automatic control of refinery processes on the basis of true vapor-pressure.

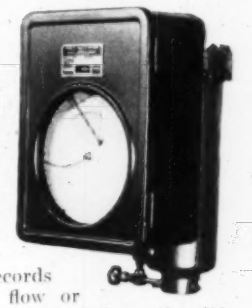
## Mica Condensers for the Laboratory

For use as secondary standards in the laboratory, the General Radio Co. announces Type 509 Mica Condensers, designed specifically for this purpose. Their large size permits high capacitance values, extending up to 1.0 μf. These condensers are put through an artificial aging process whereby the capacitance change which remains is negligible over long periods of time. The value of capacitance is measured to 0.1% and recorded on the calibration certificate. The 10 available sizes run from 0.001 to 1.0 μf. and are so chosen that a minimum of duplication is required to obtain all values in any one decade. Power factor <0.05% for all sizes. Temperature coefficient of capacitance <0.01%/°C. Mounted in two sizes of cast aluminum cases: 6"x3⅜"x2⅜" and 4⅜"x2½"x1⅞" over-all. Net weights 3½ and 2½ lbs.



## Fuel-and-air Flowmeter for Furnaces and Kilns

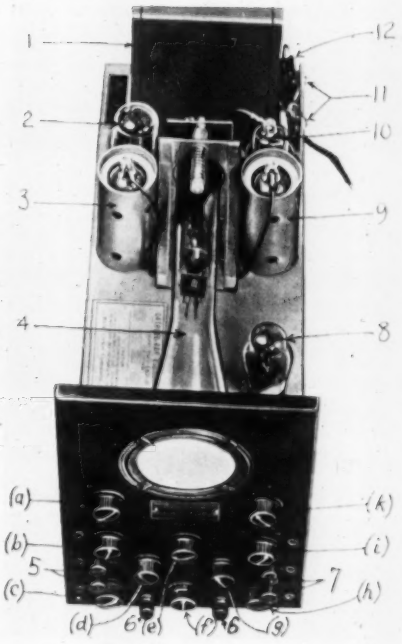
A new fuel flow-air flow meter has been developed by Bailey Meter Co. to provide operators of furnaces and kilns with an easily understandable guide which enables them to maintain a definite relation between the amounts of air and fuel supplied to the furnace, thereby securing the highest possible combustion economy. One of the two pens records the rate of oil flow or gas flow and is actuated from the differential pressure produced by an orifice in the fuel line; similarly the second pen records the flow of air supplied for combustion. At the time the meter is installed, a complete combustion test is made to determine the optimum fuel-air ratio, and the air flow mechanism is adjusted so that coincidence of the two records represents the optimum ratio. The furnace operator then strives to keep the two pens together.



In addition to serving as a combustion guide, the new meter indicates and records the rate of fuel flow in any convenient terms, and registers the total flow on a six-digit cyclometer. The integrating mechanism requires a regulated-frequency a.-c. supply, although the meter may be furnished with a spring-driven clock for the recording mechanism if an integrator is not desired in cases where frequency is not regulated. Auxiliary recorders of temperature or pressure may be included to record on the same chart with the flow records, for ease of comparison of related factors. The 12" diameter charts are uniformly graduated and are marked with direct-reading scales. Each factor is recorded in an individual color.

## Portable Cathode-ray Oscillograph

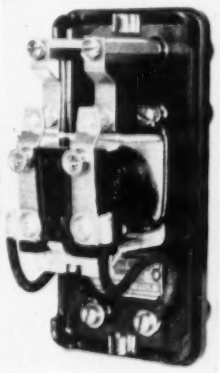
In the new "ready-to-use" a.-c.-operated cathode-ray oscillograph (Type TMV-122-B), announced by the RCA Mfg. Co., the sensitivity is guaranteed at 2 volts d.c. per inch for both vertical and horizontal deflection. Our annotated photograph is a view looking down on this instrument minus its handled housing. *Principal parts*: 1—power transformer supplying all tubes and rectifier circuits; 2—low-voltage full-wave rectifier supplying amplifier tubes; 3—vertical amplifier; 4—Type 906 cathode-ray tube with 3" screen; 5—input binding posts; 6—binding posts for external synchronizing voltage; 7—binding posts for external horizontal deflecting voltage; 8—gas triode "sawtooth" timing oscillator; 9—horizontal amplifier; 10—high-voltage half-wave rectifier supplying 1200 volts to cathode-ray tube; 11—vertical and horizontal beam centering adjustments; 12—safety switch turning off power when housing is removed. *Controls*: (*a*) intensity, also "power off" at extreme counter-clockwise end; (*b*) amplifier "A" switch for connecting input to vertical amplifier or directly to vertical deflecting plates; (*c*) regulates




height of image; (*d*) adjusts synchronizing of timing oscillator; (*e*) timing oscillator range selector, 8 ranges; (*f*) selector for synchronizing timing oscillator with voltage on vertical plates, with 60-cycle a.c. or with any external signal; (*g*) fine adjustment for timing oscillator, used in connection with *e*; (*h*) adjusts horizontal deflecting voltage; (*i*) selector switch for connecting amplifier to timing oscillator, binding posts to amplifier or binding posts to horizontal plates; (*k*) focusing control.

## Auxiliary Relays

A small, sturdy, low-priced auxiliary relay, "Type SG," for use on a.c. or d.c., is announced by Westinghouse Electric & Mfg. Co. The switchboard mounting model has a molded cover or molded cover with glass front; the front-connected panel-mounted model uses no cover. Both models have two independent contact circuits adjustable for circuit-closing or circuit-opening service. For two independent opening circuits, additional material must be added to the standard relay. Designed for continuous duty at rated voltage, up to 550 volts a.c. or 440 d.c. (ranges up to 250 volts can be used for intermittent duty up to approximately three times their continuous value). The relay can be supplied with a coil for any current value up to 5 amps. Each contact will carry 12 amps. continuous and 20 amps. for one minute. Non-inductive rating:



| Volts d.c. | Interrupting rating amperes, d.c. | Interrupting rating amperes, a.c. |
|---|---|---|
| 24 | 12 | 20 |
| 48 | 6 | 20 |
| 115 | 3 | 20 |
| 230 | 1.25 | 10 |
| 550 | 0.25 | 3 |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# INSTRUMENTS BOOK SHELF

**The Flow of Water in Pipes, Sewers and Channels; over Weirs, and off Catchments.** By GEORGE BRANSBY WILLIAMS. Chapman & Hall, Ltd., London, 1934. Cloth, 9¾ x 7¼ inches, 76 pages. Price 10s/6d.

The title of this book conveys exactly the scope of the subject matter. The treatment is principally graphic, 46 diagrams being used to present the data; in general, velocity or discharge is plotted against slope or pressure loss. The formulas on which the diagrams are based are not widely used in this country, though they are of recognized standing and are well-recommended. The Manning formula is used for brick, concrete, iron and steel conduits, the Bazin formula for earth channels, the Francis formula for rectangular weirs, and the Thomson formula for 90° V-notch weirs. The text explains the diagrams, special attention being given to the questions of run-off and flood discharges from catchments and of storm water drainage systems. The diagrams are of such size and arrangement that they are readily usable, and the book should be useful wherever quickly available data on the flow of water in conduits are required. L. M. VAN DER PYL (2.54)-B-

**The Scale in the Course of Time (Die Waage im Wandel der Zeiten).** By ARPAD KOCHM. Verlag von W. Kramer & Co., Frankfurt a/m., 1934. Paper, 6⅝ x 4¼ inches, 32 pages. Price 1 RM.

There was need for a history of this prehistoric instrument and every one concerned with the manufacture and use of scales will want to add this little booklet to his library. The story is in several chapters: I. Scales in Ancient Times; II. Scales in the Middle Ages; III. Scales in German Literature; IV. False Scales; V. City-Scales in Berlin, Nürnberg and Frankfurt a/m.; The old Frankfurt Scale Industry.

RICHARD RIMBACH (2.03)-B-

# MANUFACTURERS' NEW LITERATURE

**In this department we list each month the printed matter issued by manufacturers. Unless otherwise noted, any of the items listed may be secured free upon application to the issuing firm. Manufacturers who have not yet sent in their printed matter are invited to do so.**

C116 **Industrial Condenser Data.** General engineering data on electrolytic and oil-filled industrial condensers as well as their application to motor-starting, power-factor correction and other industrial uses, is presented in a 28-page manual and catalog just issued by the Aerovox Corporation, 70 Washington St., Brooklyn, N. Y. The catalog lists the large line of industrial units in which the organization has pioneered for many years, and facilitates the selection of proper equipment for any given application.

C117 **Spectroscopic and Other Accessories.** Catalogue F, 54 pages, lists condensing lens and mounts, mirrors, absorption tubes and cells, various types of spectroscopic slits and eyepieces, levelling tables, vacuum pumps, discharge tubes, sodium and cadmium lamps, arc and spark stands, AC-DC rectifier, pure and rare metals, Judd Lewis comparator, thermopiles, photoelectric cells, photographic materials, and publications. Adam Hilger, Ltd., 98 King's Road, London, NW1, England.

C118 **General Radio Experimenter.** The March 1935 issue contains the following articles: Waveform errors in the measurement of filter characteristics; The Stroboscope Stops the Rollator, etc. General Radio Co., 30 State Street, Cambridge A, Mass.

C119 **Transformers.** Bulletin 1002, 32-pages gives engineering data on transformers for audio amplification and transmission. American Transformer Co., 178 Emmet St., Newark, N. J.

C120 **Microprojector for Microscope.** 4-page leaflet describes this instrument. Bausch & Lomb Optical Co., Rochester, N. Y.

C121 **Polarizing Plates.** Leaflet describes the Mark's polarizing plates which produce almost completely polarized light. Physical data is also included. These plates should find many applications in scientific instruments. Polarized Products Co., P. O. Box 27, White Stone, L. I., New York.

C122 **Light Beam Galvanometer.** Very attractive broadside describes the Tag indicating and recording potentiometer controllers. The features are listed and illustrated. C. J. Tagliabue Mfg. Co., Park and Nostrand Aves., Brooklyn, N. Y.

C123 **Guild Flicker Photometer Head.** Publication No. 220 is devoted to this instrument applicable to colored light sources. Adam Hilger, Ltd., 98 King's Road, London, NW1, England.

C124—**Aquastat.** Leaflet lists the superior features of the Type TS 106 Dunco surface aquastat for efficient operation and temperature control of hot water heating systems. Struthers-Dunn, Inc., 139 N. Juniper St., Philadelphia, Pa.

C125 **Flowmeters.** Bulletin 426 is devoted to flow-meters for indicating, recording, integrating and controlling the flow of steam, gases and liquids. Bristol Co., Waterbury, Conn.

C126 **Gas Regulators.** Bulletin 27—Reliance Type "H" Regulators, Bulletin 30—Liquid Petroleum Gas Regulators; and Bulletin 34—Reliance Gas Regulators for Perfect Control. American Meter Co., 60 E. 42nd St., New York, N. Y.

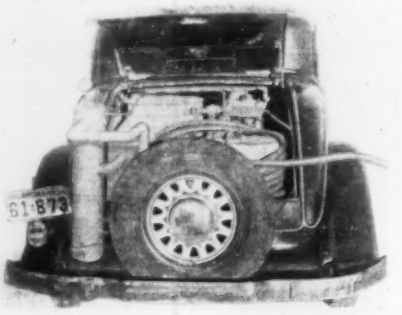
C127 **Textile Instruments.** Folder D-191 entitled "The Shadow on Your Profit Sheet" illustrates a number of optical instruments for use in textile plants. Bausch & Lomb Optical Co., Rochester, N. Y.

C128 **Cathode Ray Oscillograph.** Form 9511 illustrates the construction of the RCA portable oscillograph and describes how it works. RCA Manufacturing Co., Inc., Camden, N. J.

C129 **Illumination Control.** Circular B-1005-A outlines the need for illumination control. The Model 709 illumination control relay is described. Weston Electrical Instrument Corp., Newark, N. J.

## Test Car Column for Gas and Gasoline Analysis

The Gregory Test Car Column has been brought out by the Refinery Supply Co. to meet the need for an analytical method combining the mobility and



simplicity of the test car and charcoal method with the precision and completeness of the low-temperature methods now used in laboratories. Its applications are (1) gas and gasoline analyses in the field and (2) determinations of (a) gasoline content of natural gas and (b) operating efficiencies of plants. Successful solution of the problem was found in using (1) the car's battery for heating the base of the column and (2) dry ice for cooling the top of the column. A special cycle has been developed whereby the dry ice is used only when needed, and an insulated chamber takes the standard 50-lb. cake of dry ice now obtainable in many towns. Among the "laboratory" tests now made feasible in the field are Engler distillations and vapor-pressure determinations. It is possible to stop the fractionation at a proper point, withdraw, measure and check a gasoline of any desired grade, so that the interested operator obtains timely and valid evidence of the amount and grade of gasoline to be extracted from the gas without resource to uncertain conversion factors.

## Two New Rotameters

For marine service and also for gas-liquid mixtures, a new model "Rotameter" is announced by Schutte & Koerting Co. Its feature (see Fig. 1) is a central guide rod to prevent lateral displacement of the rotary float, which therefore cannot strike and break the glass tube. For metering pulsating flows any model of the "Rotameter" may be equipped with a dash-pot as shown in Fig. 2.

Fig. 1

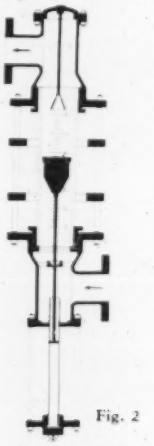


Fig. 2

## Pressure, Draft and Differential Recorders

Employing the same slack-leader diaphragm elements which have long been embodied in Hays sensitive indicating gages for draft, etc., a new line of

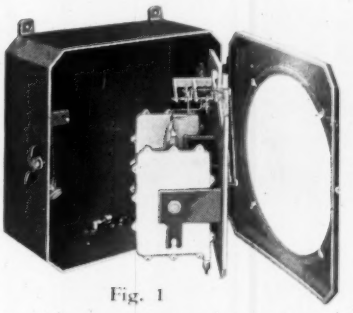


Fig. 1

10" chart recorders is announced by the Hays Corp. for pressure, draft, pressure-and-draft, and differential pressure in a total of 29 ranges. The new line comprises two distinct styles of instruments: "*Series OT*" recorders are housed in square cases measuring 13"x14"x7". They are available in 14 draft or pressure ranges from 0-0.5 to 0-100" water and in 8 pressure-and-draft ranges from +0.1/0/—0.4 to +5/0/—5" water. They may be obtained in 2-pen styles (see Fig. 1). "*Series OH*" recorders contain large "supersensitive" elements and are housed in rectangular cases (Fig. 2) measuring 17"x27½"x9". They are available in ranges as low as 0-0.1" water. 2-pen models are available but only one of the two elements can be the large "supersensitive" type; the other must be for a range of at least 0-5" water.

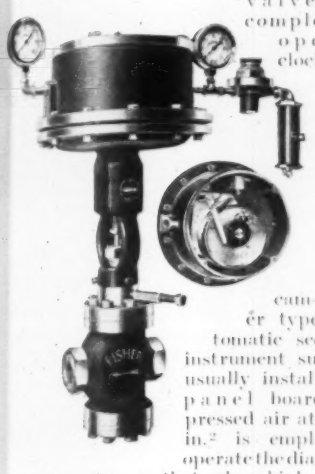
Fig. 2

## A.S.T.M. Daylight Lamp

In accordance with new specifications adopted in June, 1934, by the A.S.T.M., the C. J. Tagliabue Mfg. Co. offers a new Daylight Lamp for color determinations which is said to give an illumination more closely approximating ideal daylight conditions for color tests than any lamp designed up to this time. This new adjustable type, TAG-Macbeth Daylight Lamp is suitable for use with the TAG Saybolt Chronometer, A.S.T.M. Serial D156-34T; the TAG Union Colorimeter, A.S.T.M. Serial D155-34T and D218-34T; also the TAG Robinson Colorimeter. The company states that its Union Colorimeters are now equipped with this new Daylight Lamp, attached by means of an adjustable bracket. Where Union Colorimeters are now in use, the old lamp should be removed and the new lamp procured in order to meet standard specifications. In addition, the specifications require the insertion, in the Union Colorimeter, of a piece of new flashed opal diffusion glass which TAG can now supply to bring the instrument up-to-date.

## Automatic Pressure-time Cycle Controller

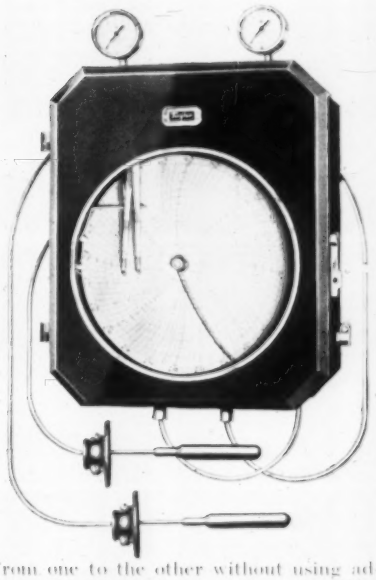
Compactness is chief design characteristic of the new cycle controller brought out by the Fisher Governor Co., one assembly combining a diaphragm-motor valve with a complete air-operated, clock-driven



cam-and-rider type of automatic sequencing instrument such as is usually installed on a panel board. Compressed air at 20 lbs./in.$^2$ is employed to operate the diaphragm-motor valve, so that when high-pressure air or gas is the controlled medium, no separate compressor is required, the valve-operating medium at 20 lbs. being obtained through a reducer from the high-pressure line itself. Standard 24-hour clocks available at this date provide 1-, 6- or 24-hour cam rotation periods. Cam blanks are circular plates of rustless metal, on which notches are readily cut and filed in the field. Standard sizes at this date run up to 2" pipe size but larger sizes are available. Principal applications reported are on gas-lift in the oil fields (for which this controller was especially developed).

## Dual Control System

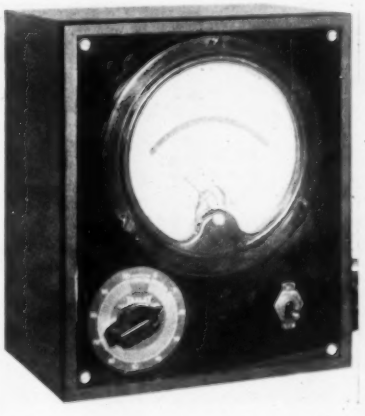
A "Reset" controller has been brought out by Taylor Instrument Companies to meet applications where it is desired (1) to maintain a fixed or widening *differential between two variables*, one of which is under control; or (2) to change the control point of a particular process in accordance with *variations in a secondary system*, such changes being brought about in a predetermined relationship. It can be applied to control temperature, pressure or combination of both, or either of these combined with flow or liquid level. The instrument comprises two separate systems, each with its own functions and yet interlocked so as to produce the desired predetermined results. Control is effected by the controlling system alone through the standard "Fulscope" mechanism and the universal sensitivity adjuster (see *Instruments*, April 1934, page 81) by means of which the instrument can be fitted to the exact operating conditions of the apparatus. The resetting system serves only to change the setting point of the controlling system, through a simple linkage. The reset controller accomplishes, automatically, the same results as a manual key adjustment of the control point. The resetting linkage is adjustable through a wide range, permitting control point changes to be made in a great variety of ratios between controlling and resetting systems. Adjustments can be made so that the resetting is accomplished either with *direct or inverse ratio*, and the instrument is easily changed in the field



from one to the other without using additional parts. Likewise, the controlling system can be changed from direct to reverse-acting. (Inverse ratio adjustments provide for a decrease in the controlled condition with an increase in the adjusting condition, and vice versa; direct ratio adjustments cause an increase in the controlled condition with an increase in the adjusting condition, and vice versa.) The instrument furnishes a record of both the controlled and leading values. The chart is rotated by an electric clock.

## Photocell Colorimeter

Color matching on a quantitative basis is the purpose of a new photoelectric instrument brought out in two models by the M-R-H Laboratories. It contains a



"daylight" lamp and operates by comparison of reflections, so that it may be used under any illumination. Area needed for matching is a 2"circle. Procedure consists of (1) placing instrument on standard sample, (2) adjusting sensitivity until a reading of, say, "600" is obtained on scale, (3) placing instrument on test sample and taking the reading. The sensitivity adjustment is such that full-scale deflection may be obtained for dark shades as well as for highly reflective surfaces. Case is Bakelite. Available in flush-indicator model 8"x6"x5" (illustrated) or in a model consisting of an 8"x4"x3" case with an inclined miniature indicator resting on its top.

C130 **Selective Relay.** Sheet SR1-L is devoted to the applications and construction a selective relay, which provides a means of controlling the operation of one system when a definite time signal is transmitted over the second system in which the electromagnet of the relay is connected. Gamewell Co., Newton, Mass.

C131 **Microphotometer.** Leaflet NOMI-34 describes a non-recording microphotometer which consists of a microscope the condenser of which is replaced by a lantern, and the eye piece by a Moll thermopile. P. J. Kipp & Zonen, Delft, Holland.

C132 **Potentiometers.** The following potentiometers are described in the literature of the Lewis Engineering Co., Naugatuck, Conn. (These sheets have no identifying marks): A Small Portable Serviceman's Potentiometer; and A Pyrometer Potentiometer.

C133 **Beat Frequency Oscillator.** Bulletin No. 28 gives engineering data on the Type TMV-52-E beat frequency oscillator, range 20 to 17,000 cycles. RCA Victor Co., Inc., Camden, N. J.

C134 **Rotary Selector Switch.** Leaflet illustrates an 18 point switch for thermocouple pyrometers, potentiometers, voltmeters, multiple shunt ammeters, etc. Lewis Engineering Co., Naugatuck, Conn.

C135 **Universal Photo-optical Bench.** Described in a four-page bulletin. It was designed to facilitate certain phases of photo-macrography, which have presented great difficulties heretofore. E. Fuess, Inc., 245 West 55 St., New York, N. Y.

C136 **Carbon Monoxide, the Killer.** The immediate need is for rapid and widespread dissemination of clean-cut information on the habits and toxic effects of carbon monoxide; and on the equipment developed severally to detect its presence, protect the individual and resuscitate the victim. All of that information is available under one cover in this publication prepared by Mine Safety Appliances Company, Pittsburgh, Pa.

C137 **Humidity Indicators.** Bulletin No. H-301 describes a relative humidity and temperature indicator, a psychrometer with motor driven fan and a sling psychrometer. Johnson Service Co., Milwaukee, Wis.

C138 **Relays.** Catalog Section 11-350 is a 4-page bulletin covering the application, distinctive features, list prices and dimensions of the Type 86 auxiliary relays, switchboard and panel mounting types for a-c. or d-c. use. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

C139 **Differential Thermostat.** Bulletin 71 contains engineering data on the Type 691 thermostat for cooling and air conditioning. Detroit Lubricator Co., Trumbull Ave., Detroit, Mich.

C140 **Solving Industrial Crimes, Case No. 6.** Short true story showing a saving of $3240.00 by making a survey of motor loads in a flour mill. Esterline Angus Co., Indianapolis, Ind.

C141 **Biddle's Business.** Bulletin 1395 is a general bulletin briefly describing and illustrating the instruments imported by James G. Biddle Co., 1211 Arch St., Philadelphia, Pa.

C142 **Refrigeration.** Catalog 300, 32 pages, describes and gives data on indicators, recorders and controllers for refrigeration and cold storage. Taylor Instrument Companies, Rochester, N. Y.

C143 **Trip-Free Air Circuit Breakers.** GEA-1662A gives features and dimensions, as well as other data on these circuit breakers. General Electric Co., Schenectady, N. Y.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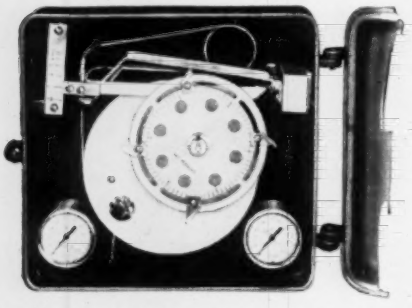
## Sequence-repeat Controller

Instead of employing the conventional fixed cam to time the intermittent operation of a diaphragm valve or other diaphragm-operated devices, the "Taylor Intermitter" just brought out by Taylor Instrument Companies has a circular cam on which the proper number of actuating lugs may be placed; the number (up to 20) corresponding with the number of operations to be performed during the rotation of the cam. The duration of each operation is adjustable by moving the bracket carrying the nozzle (upper left corner of case) so that its scribe mark is opposite the desired time interval on the scale; the higher the position of the nozzle, the shorter the period of nozzle closure and the duration of operation. Any change in either the number of durations of the operations, or the interval between operations, is thus made possible without replacing or cutting the actuating cam.

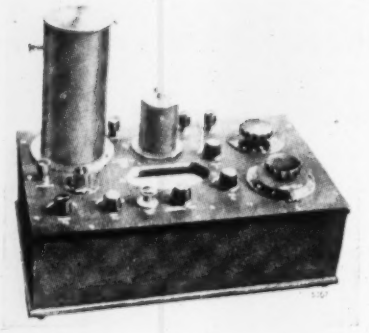


The cam is driven by a spring clock, available in 1-hour, 6-hour, 12-hour or 24-hour periods of rotation. Electrically driven clocks with identical periods can be supplied. The instrument is available in two types—Reverse-acting: lugs to close nozzle, applying pressure to diaphragm motor. Direct-acting: lugs to open nozzle, relieving pressure from diaphragm motor. It may be mounted on any diaphragm motor or in any convenient adjacent location. Also, it is possible to operate more than one diaphragm valve or similar device from the same instrument, the number depending upon the operating conditions and the nature of the control required.

An overpressure release protects the diaphragm motor from excessive pressures in the event of reducing-valve failure. Compressed air or gas at 25 lb./in.$^2$ is specified.

## Electrometer-tube Type pH Meter, Electrodes

Until recently, the use of the glass electrode is said to have been limited to special work because of practical difficulties of measurement: sensitive electrometers requiring skill, and high resistance of glass membrane employed requiring extreme care in shielding the apparatus from electrostatic and leakage effects. An "Electrometer Valve pH Meter" as suggested by C. Morton has been brought out by the Cambridge Instrument Co. The direct-reading instrument, calibrated in pH units, requires neither technical knowledge nor reference to tables. The new circuit employs the electrometer tube as a null-point detector, thus eliminating—it is said—the troubles given by most thermionic-tube instruments. The new instrument is automatically compensated for changes in grid bias and anode voltage. Although

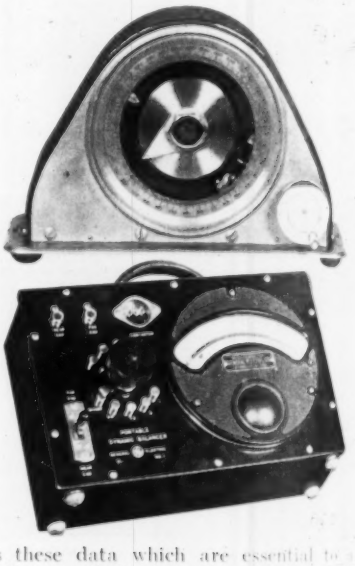


designed for use with the new Morton Glass Electrode it may be used with any electrode system over a wide temperature range. It is calibrated for a range of 14 pH units, each dial division corresponding to 0.02 pH. The new *Morton Glass Electrode System* is said to have the advantage that the electrode cannot be "poisoned," is unaffected by powerful oxidizing and reducing agents and in contact with complex biological fluids, which may be viscous, colored or turbid, the glass surface instantly exhibits a steady potential determined by the pH concentration. High-conductivity glass is used in the construction of the electrodes. Electrostatic shielding and exceptional care in insulation are said to be unnecessary, and determinations can be made in 30-60 seconds with an accuracy of $\pm 0.01$ pH.

## New Method, Equipment for Dynamic Balancing

A new method for the dynamic balancing of heavy rotating machinery in the field under normal operating conditions, and new portable equipment for obtaining a direct and exact solution of this problem are announced by the General Electric Co. With the new method and equipment (both of which were developed by Ernest L. Thearle of the G-E Research Laboratory), the balancer is taken to the machine instead of the machine to the balancer. The method deals directly with that component of vibration which occurs at running speed frequency, caused by mass unbalance in the rotating member—the only component which may be eliminated by the addition of balance weights. The new equipment consists of two special generators, a contactor (Fig. 1), and an instrument-and-control box (Fig. 2). The generators are similar to the G-E "vibration-velocity unit" (see *Instruments*, Oct. 1934, page 217). One of them is attached to each bearing pedestal of the unbalanced machine, the contactor is coupled to the machine's shaft so as to rotate with it, and both generators and contactor plugged into the control box. The generators produce an alternating emf. proportional to the vibration velocity of the pedestals. In the contactor the contact assembly with attached pointer can be rotated through a complete circle and the phase read on the full-circle scale. The indicator is a highly damped d.-c. micro-ammeter, arranged with a tumbler switch for connecting it to either generator and a ratio switch to control its sensitivity.

Displacement of the pedestal in vibration is sinusoidal and its first derivative, vibration velocity, is also sinusoidal, being zero when displacement is at its maximum and greatest when displacement is zero. Since the generators produce an emf. proportional to vibration velocity, the current through the indicator is sinusoidal and proportional to vibration velocity. The circuit being closed by the contactor during only half a revolution, the indicator receives only half a complete cycle of current: a complete positive half-wave or a complete negative half-wave or complementary fractions of each half-wave. If it receives equal fractions of the positive and negative half-waves, it reads zero; and then the point on the contactor scale halfway between the points at which contact is made and broken indicates the angular position of maximum vibration displacement: the phase of the vibration. The contact assembly is then rotated 90°, at which point the indicator receives a full positive or negative half-wave: its reading at this point represents magnitude of unbalance. With the two generators, readings of phase and magnitude of unbalance are readily taken at both ends of the unbalanced machine. It



is these data which are essential to a solution of the balancing problem and which the new portable dynamic balancer makes simply and quickly obtainable. In placing a machine in balance by the new method, only three balancing runs are necessary. The first is made with the machine in its normal unbalanced condition; readings of phase and magnitude taken at the near and far ends are entered on a standard calculation sheet. The second run is made with a single known weight of any reasonable amount placed in any position on the near end of the machine rotor. Readings are again taken for the near and far ends and entered on the calculation sheet. The third run is made in the same manner as the second but with a weight on the far end. A series of simple calculations are then made on the standard sheet, giving a solution which indicates the values and positions of the final corrective weights which will balance the rotor.

**Leeds & Northrup**, Philadelphia, and **George Kent, Ltd.**, England, have entered into an agreement whereby the latter will sell its electrochemical instruments in the U. S. through the former. Sales of Kent meters in the U. S. through Builders Iron Foundry are not affected.

The **Central Scientific Co.** has moved into two large buildings extending from Hermitage to Paulina streets along Irving Park Blvd., Chicago.

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CONTENTS FOR MAY, 1935

Volume 6, Number 5

Physics Forum:

Nuclear Spins and Moments. I

Contributed Articles:

Electron Diffraction Camera

Leads and the Formula in Electric Calorimeter Calibration

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**Damper**
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Pioneer Instrument Co.
Taylor Instrument Cos.
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Bailey Meter Co.
Bristol Co.
Brown Instrument Cp.
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**Filter Rate**
Bristol Company
Brown Instrument Co.
Foxboro Co.
**Flow**
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Bailey Meter Co.
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Pioneer Instrument Co.
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J. P. Friez & Sons, Inc.
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Brown Instrument Co.
Foxboro Co.
J. P. Friez & Sons, Inc.
Taylor Instrument Cos.
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Weston Elec. Inst. Corp.
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Bailey Meter Co.
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Bailey Meter Co.
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Brown Instrument Co.
Foxboro Co.
Pioneer Instrument Co.
Taylor Instrument Cos.
Wilbin Instrument Co.

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Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
Thwing Instrument Co.
Wilbin Instrument Co.
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Foxboro Co.
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Taylor Instrument Cos.
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Weston Elec. Inst. Corp.
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Thwing Instrument Co.
Wilbin Instrument Co.
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Foxboro Co.
J. P. Friez & Sons, Inc.
Pioneer Instrument Co.
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Thwing Instrument Co.
Wilbin Instrument Co.
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Brown Instrument Co.
Foxboro Co.
J. P. Friez & Sons, Inc.
Taylor Instrument Cos.
Wilbin Instrument Co.
**Vacuum**
Bailey Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.
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Foxboro Co.
Taylor Instrument Cos.
Wilbin Instrument Co.
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Ward Leonard Elec. Co.
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Bristol Company
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Pioneer Instrument Co.
Taylor Instrument Cos.

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**Revolution**
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Brown Instrument Co.
Pioneer Instrument Co.
**Stroke**
Bristol Company

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American Meter Co.

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Roller-Smith Co.

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Bristol Company

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Westinghouse E. & M.Co.

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Rawson Elec. Inst. Co.
Weston Elec. Inst. Corp.

**EARTH CURRENT METERS**
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Roller-Smith Co.

**ELECTRIC TELEMETERS—See Remote Metering Equipment**

**ELECTRIC WAVE FILTER SECTIONS**
General Radio Company

**ELECTRONIC METERS**
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General Radio Co.
Rawson Elec. Inst. Co.
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Ward Leonard Elec. Co.

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George Sidney Binckley
Brown Instrument Co.
Pioneer Instrument Co.
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Bailey Meter Co.
George Sidney Binckley
Brown Instrument Co.
Foxboro Co.
Pioneer Instrument Co.
Taylor Instrument Cos.
**Integrating & Recording**
American Meter Co.

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Brown Instrument Co.

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Brown Instrument Co.
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General Electric Co.
**Vacuum**
General Electric Co.
Taylor Instrument Cos.
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Brown Instrument Co.
Foxboro Co.
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Brown Instrument Co.
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Roller-Smith Co.
Taylor Instrument Cos.
Thwing Instrument Co.
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Weston Elec. Inst. Corp.

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George Sidney Binckley

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Taylor Instrument Cos.

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Foxboro Co.
J. P. Friez & Sons, Inc.
Taylor Instrument Cos.

**ILLUMINOMETERS**
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Weston Elec. Inst. Corp.

**INDICATORS—See Gages**

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General Electric Co.
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Wilbin Instrument Co.

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Taylor Instrument Cos.
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George Sidney Binckley
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Foxboro Co.
Pioneer Instrument Co.
Taylor Instrument Cos.
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Brown Instrument Co.
Foxboro Co.
J. P. Friez & Sons, Inc.
Taylor Instrument Cos.
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**Flow**
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Bailey Meter Co.
George Sidney Binckley
Brown Instrument Co.
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Bailey Meter Co.
Bristol Company
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Bristol Company
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Foxboro Co.
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American Meter Co.
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Foxboro Co.
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Thwing Instrument Co.

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George Sidney Binckley
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Foxboro Co.
J. P. Friez & Sons, Inc.
Pioneer Instrument Co.
Taylor Instrument Cos.

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George Sidney Binckley
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Brown Instrument Co.
Foxboro Co.

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General Electric Co.

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Roller-Smith Co.
Westinghouse E. & M.Co.
Weston Elec. Inst. Corp.

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Roller-Smith Co.
Weston Elec. Inst. Corp.

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Testing Machines, Inc.

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General Electric Co.
General Radio Co.
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Roller-Smith Co.
Westinghouse E. & M.Co.
Weston Elec. Inst. Corp.

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General Electric Co.
Rawson Elec. Inst. Co.
Roller-Smith Co.
Taylor Instruments Cos.
Thwing Instrument Co.
Westinghouse E. & M. Co.
Weston Elec. Inst. Corp.

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Gaertner Scientific Corp.

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Foxboro Co.
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Bristol Company
Foxboro Co.
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Gaertner Scientific Corp.

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Bristol Company
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Taylor Instrument Cos.

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General Electric Co.
Thwing Instrument Co.
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Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos.

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Foxboro Co.
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Taylor Instrument Cos.
**Sling**
J. P. Friez & Sons, Inc.
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Taylor Instrument Cos.
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Taylor Instrument Cos.
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Roller-Smith Co.
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Testing Machines, Inc.
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Thwing Instrument Co.

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Roller-Smith Co.

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Rawson Elec. Inst. Co.
Roller-Smith Co.
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Weston Elec. Inst. Corp.

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J. P. Friez & Sons, Inc.
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General Electric Co.
General Radio Co.
Kurman Electric Co.
Pioneer Instrument Co.
Rawson Elec. Inst. Co.
Roller-Smith Co.
Shallcross Mfg. Co.
Thwing Instrument Co.
Westinghouse E. & M. Co.
Weston Elec. Inst. Corp.

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Roller-Smith Co.
Thwing Instrument Co.

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Gaertner Scientific Corp.

**SPECTROMETERS**
Bausch & Lomb Opt. Co.
Gaertner Scientific Corp.

**SPECTROPHOTOMETERS**
Bausch & Lomb Opt. Co.
Gaertner Scientific Corp.

**SPECTROSCOPES**
Bausch & Lomb Opt. Co.
Gaertner Scientific Corp.

**SPEED INDICATORS**
**See Tachometers**

**SPEED RECORDERS**
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Brown Instrument Co.
J. P. Friez & Sons, Inc.
Thwing Instrument Co.

**SPEED REGULATORS**
Ward Leonard Elec. Co.

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Weston Elec. Inst. Corp.

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**STROBOSCOPES**
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Taylor Instrument Cos.

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Westinghouse E. & M. Co.

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Westinghouse E. & M. Co.
Weston Elec. Inst. Corp.

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**Electrical**
General Radio Co.

**SYNCHRONOUS MOTORS**
General Electric Co.
Pioneer Instrument Co.
Westinghouse E. & M. Co.

**TACHOMETERS**
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Bristol Company
Brown Instrument Co.
Foxboro Co.
Pioneer Instrument Co.
Roller-Smith Co.
Thwing Instrument Co.
Westinghouse E. & M. Co.
Weston Elec. Inst. Corp.

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Brown Instrument Co.

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Gaertner Scientific Corp.

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Thwing Instrument Co.
**Magnetic**
Kurman Electric Co.
**Paper**
Testing Machines, Inc.
Thwing Instrument Co.
Westinghouse E. & M. Co.
**Penetration**
Thwing Instrument Co.
**Stiffness & Bending**
Testing Machines, Inc.
Thwing Instrument Co.
**Stretch**
Testing Machines, Inc.
Thwing Instrument Co.
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Testing Machines, Inc.
Thwing Instrument Co.
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Thwing Instrument Co.
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Rawson Elec. Inst. Co.
Roller-Smith Co.
Weston Elec. Inst. Corp.

**THERMOMETERS**
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Bristol Company
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## ADVERTISERS' INDEX


| | |
|---|---|
| American Meter Company | 125 |
| Bailey Meter Co. | 120 |
| Hotel Barium | A7 |
| Bausch & Lomb Optical Co. | A6 |
| George Sydney Binckley | 125 |
| The Bristol Co. | Back Cover |
| The Brown Instrument Co. | A5 |
| H. F. Byram | 135 |
| Chace Valve Co. | A6 |
| Clifford Mfg. Co. | 124 |
| Wilbur B. Driver Co. | A6 |
| The Foxboro Co. | Inside Front Cover |
| Julien P. Friez & Sons | 122 |
| Gaertner Scientific Co. | A2 |
| General Physical Labs. | 135 |
| General Radio Co. | A2 |
| Claud S. Gordon Co. | Inside Back Cover |
| Heise Bourdon Tube Labs. | A2 |
| Hickok Electrical Instrument Co. | 126 |
| Illinois Testing Labs. | 135 |
| Instruments Publishing Co. | A1, A6 |
| Littelfuse Laboratories | A8 |
| Minneapolis-Honeywell Regulator Co. | A5 |
| Pioneer Instrument Co. | 123 |
| Pyrometer Instrument Co. | 126 |
| Rawson Electrical Instrument Co. | 133 |
| Review of Scientific Instruments | A5 |
| Roller-Smith Co. | A2 |
| Shallcross Mfg. Co. | 133 |
| Standard Electric Time Co. | 134 |
| Thwing Instrument Co. | 134 |
| Trofimov School of Inventive Practice | 121 |
| Weston Electrical Instrument Corp. | A3 |